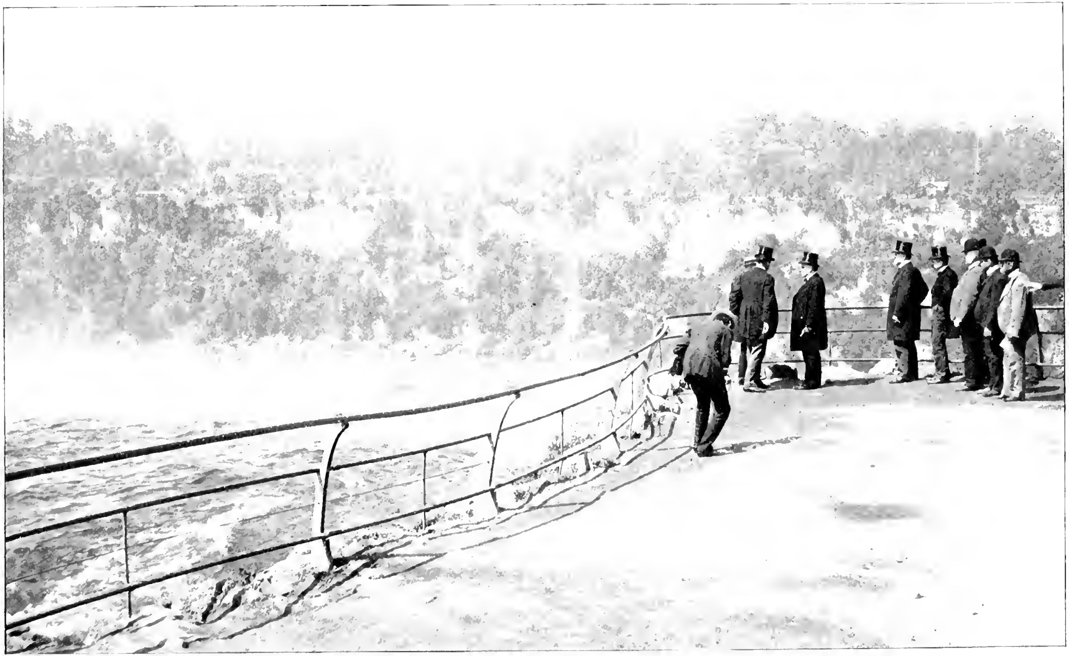
EIGHTEENTH ANNUAL REPORT
OF THE
COMMISSIONERS
OF THE
STATE RESERVATION AT NIAGARA
OCT. 1, 1900 - SEPT. 30, 1901



President McKinley at Niagara September 6, 1901.
(Frontispiece)

Governor Odell and Party at Niagara July 27, 1901.
(Frontispiece 2nd)

Andrew H. Green

EIGHTEENTH ANNUAL REPORT

OF THE

COMMISSIONERS

OF THE

State Reservation at Niagara

FROM OCTOBER 1, 1900,
TO SEPTEMBER 30, 1901.

TRANSMITTED TO THE LEGISLATURE FEBRUARY 24, 1902.

ALBANY
J. B. LYON COMPANY, STATE PRINTERS
1902

STATE OF NEW YORK.

No. 45.

IN ASSEMBLY,

FEBRUARY 24, 1902.

EIGHTEENTH ANNUAL REPORT

OF THE

Commissioners of the State Reservation at Niagara.

To the Honorable the Speaker of the Assembly:

Sir.—I herewith transmit for presentation to the Legislature the Eighteenth Annual Report of the Commissioners of the State Reservation at Niagara for the fiscal year ended September 30, 1901.

Respectfully yours,

ANDREW H. GREEN,

President.

EIGHTEENTH ANNUAL REPORT

OF THE

COMMISSIONERS

OF THE

State Reservation at Niagara.

FOR THE FISCAL YEAR FROM

OCTOCER 1, 1900, TO SEPTEMBER 30, 1901.

Commissioners.

ANDREW H. GREEN, President.

GEORGE RAINES, CHARLES M. DOW,

THOMAS P. KINGSFORD, ALEXANDER J. PORTER.

Treasurer and Secretary.

PETER A. PORTER, Jr.

Superintendent.

THOMAS V. WELCH.

REPORT.

To the Honorable the Legislature of the State of New York:

The Commissioners of the State Reservation at Niagara, as required by law, submit their report for the fiscal year begun October 1, 1900, and ended September 30, 1901, this being their eighteenth annual report.

The two stone arched bridges connecting the mainland with Goat Island, which were being built at the date of the last report, are now in use by the public. The approaches have been filled, graded and planted. The building of these permanent stone bridges was the most important work of the year. It is also the greatest work of construction accomplished since the establishment of the State Reservation at Niagara.

The new Shelter building was completed July 4, 1901, and has been partly furnished. It affords many conveniences and accommodations for the public, as well as offices for the administration of the affairs of the Reservation.

Photographs of the stone arch bridges and of the Shelter building are herewith submitted.

A new bridge from Goat Island to Terrapin Point at the Horseshoeshoe Falls has been constructed; new cables, anchors, needle beams and braces have been attached to the suspension bridges to the Three Sister Islands, and the woodwork of the bridges renovated.

The Cave of the Winds building on Goat Island has been moved to a more suitable location. The frame structure in Prospect Park, adjacent to the new Shelter building, has been taken down.

On September 27th the new bridges from the mainland to Goat Island, the new Shelter building and other improvements were inspected by Governor Odell, Senator Ellsworth, President pro tem. of the Senate, Senator Higgins, Chairman of the Finance Committee of the Senate, Assemblyman Allds, Chairman of the Ways and Means Committee of the Assembly, and other State officers.

The improvements and needs of the Reservation were explained in detail to the Governor and his party, who expressed deep interest in the work of the Commission.

On September 6th the Reservation was visited by President McKinley and party three hours before the assassination of the President at the Pan-American Exposition at Buffalo.

It is estimated that the Pan-American Exposition at Buffalo brought to the State Reservation three millions of visitors. No disorder or accident occurred within the State Reservation.

The following is an estimate and detailed statement of the work necessary to be done, and the expenses of maintaining the Reservation for the fiscal year ending September 30, 1903:

Statement of Needed Improvements.

For completing stone arch bridges..................	$4,454 14
For safety brakes for Inclined Railway..............	1,000 00
For alteration of Inclined Railway building..........	910 13

These improvements may be made by the reappropriation of $6,364.27 of the unexpended balance of the $20,000 appropriated for extraordinary expenditures for care and maintenance during the

year 1901, by reason of the Pan-American Exposition. If this reappropriation is made, no new appropriation will be required for improvements during the coming year. Owing to the work upon the stone arched bridges and the great numbers of visitors from the Pan-American Exposition, the sum of $6,500 appropriated last year for the improvement of the water supply has not yet been expended.

Plans and estimates have been obtained, and the work of installing a system of water mains, as far as the appropriation allows, will be done the coming spring.

One thousand dollars appropriated last year for grading and tree planting has not yet been expended.

A plan and estimate for a lighting system has been obtained. The estimated cost is over $18,000, which is more than twice the amount of the appropriation of $7,000 made last year. As soon as the weather will permit in the spring, the work will be done as far as the appropriation of $7,000 will allow. When the current of the Niagara Falls Power Company is brought to the Reservation for use without charge, as provided by law, the question of operating the Inclined Railway by electricity will be submitted for consideration.

Ordinary Maintenance.

The appropriation made for ordinary maintenance during the current year is $25,000. The estimate of receipts for the past fiscal year, made in the last report, was $21,800. The actual receipts by the Superintendent, paid into the State treasury, were $21,710.40 for the fiscal year, and for the calendar year 1901 $22,635.10, or within $2,364.90 of the amount appropriated for ordinary maintenance of the Reservation. The large increase in the amount of receipts was due to the crowds attracted to the Reservation by the Pan-American Exposition at Buffalo.

The following is our estimate of the amounts required for ordinary maintenance for the fiscal year ending September 30, 1903:

For salaries and traveling expenses................	$5,600 00
For Reservation police and caretakers..............	8,100 00
For labor	13,800 00
For materials, tools, etc..........................	7,500 00
	$35,000 00

The appropriation of $25,000 made each year for ordinary maintenance has been found to be insufficient, and each year we have been obliged to dispense with necessary labor toward the close of the fiscal year, when greatly needed to keep the grounds in order. The amount will be more inadequate in the future, because the care of the new shelter building requires additional labor. The new stone arch bridges to the islands are not provided with gates, thus requiring the service of watchmen day and night, and the increasing amount of territory under cultivation requires an additional amount for care and mainetenance. For these reasons $35,000 is asked for care and maintenance, instead of the $25,000 usually appropriated.

Estimated Receipts.

The following is our estimate of the receipts for the fiscal year ending September 30, 1902:

Inclined Railway..................................	$8,000 00
Cave of the Winds.................................	1,200 00
Steamboat landing	500 00
Carriage service	100 00
	$9,800 00

The Superintendent in his report has made a detailed statement of the work of the Commission for the past year. The report of the Superintendent and that of the Treasurer and Secretary are hereto appended, also the contracts and specifications for the stone arch bridges, and three chapters of Bulletin of the New York State Museum, Frederick J. H. Merrill, Director, No. 45, vol. 9, April, 1901, Guide to the Geology and Paleontology of Niagara Falls and Vicinity, by Amadeus W. Grabau S. D.

Respectfully submitted,

ANDREW H. GREEN,

President.

GEO. RAINES,

THOMAS P. KINGSFORD,

CHAS. M. DOW,

ALEXANDER J. PORTER,

Commissioners of the State Reservation at Niagara.

Report of the Treasurer

For the Year Beginning October 1, 1900, and Ending September 30, 1901.

Report of the Treasurer.

THE COMMISSIONERS OF THE STATE RESERVATION AT NIAGARA, In Account with PETER A. PORTER, JR., Treasurer, for the Fiscal Year Begun October 1, 1900, and Ended September 30, 1901.

1900.				
Oct.	1.	Balance on hand this date		$37 82
		MAINTENANCE RECEIPTS.		
Oct.	18.	Quarterly advance from State Comptroller	$6,250 00	
1901.				
Jan.	24.	Quarterly advance from State Comptroller	6,250 00	
April	23.	Quarterly advance from State Comptroller	6,250 00	
July	17.	Quarterly advance from State Comptroller	6,250 00	
				25,000 00
		Special appropriation as per Chap. 569, *Laws of* 1899 ($30,000):		
1900.				
Oct.	31.	Payment by State Comptroller on account	$4,910 50	
Dec.	14.	Payment by State Comptroller on account	4,145 45	
	31.	Payment by State Comptroller on account	5 25	

1901.			
Jan. 21.	Payment by State Comptroller on account	$765 00	
Feb. 7.	Payment by State Comptroller on account	3,504 55	
April 19.	Payment by State Comptroller on account	2,569 42	
May 22.	Payment by State Comptroller on account	1,071 87	
Sept. 11.	Payment by State Comptroller on account	8,151 87	
			$25,123 91

Special appropriation as per Chap. 420, *Laws of* 1900 ($120,000):

1900.		
Oct. 11.	Payment by State Comptroller on account	$264 75
22.	Payment by State Comptroller on account	8,953 78
31.	Payment by State Comptroller on account	162 82
Nov. 12.	Payment by State Comptroller on account	252 00
21.	Payment by State Comptroller on account	18,224 00
26.	Payment by State Comptroller on account	1,583 23
Dec. 17.	Payment by State Comptroller on account	1,054 99

1900.			
Dec.	24.	Payment by State Comptroller on account	$7,803 00
	31.	Payment by State Comptroller on account	302 60
1901.			
Jan.	18.	Payment by State Comptroller on account	652 39
Feb.	15.	Payment by State Comptroller on account	472 54
March	14.	Payment by State Comptroller on account	435 08
	28.	Payment by State Comptroller on account	13,149 69
April	13.	Payment by State Comptroller on account	431 47
	19.	Payment by State Comptroller on account	867 00
May	16.	Payment by State Comptroller on account	4,060 45
June	10.	Payment by State Comptroller on account	3,323 84
	15.	Payment by State Comptroller on account	7,599 00
July	10.	Payment by State Comptroller on account	142 50
	11.	Payment by State Comptroller on account	858 65
	25.	Payment by State Comptroller on account	10,132 00

1901.			
July 29.	Payment by State Comptroller on account	$43 03	
Aug. 16.	Payment by State Comptroller on account	715 32	
31.	Payment by State Comptroller on account	1,734 00	
Sept. 13.	Payment by State Comptroller on account	327 02	
30.	Payment by State Comptroller on account	54 59	
			$83,599 74

Special appropriation as per Chap. 420, *Laws of* 1900 ($3,000):

1901.			
May 16.	Payment by State Comptroller on account	$2,800 00	
June 15.	Payment by State Comptroller on account	4 75	
July 17.	Payment by State Comptroller on account	193 74	
			2,998 49

Special appropriation as per Chap. 419, *Laws of* 1900 ($5,000):

1900.			
Oct. 11.	Payment by State Comptroller on account	$548 25	
31.	Payment by State Comptroller on account	86 15	
Nov. 12.	Payment by State Comptroller on account	141 39	
			775 79

Special appropriation as per Chap. 645, *Laws of* 1901 ($44,665.15):

1901.				
June	13.	Payment by State Comptroller on account	$3,011 06	
	15.	Payment by State Comptroller on account	194 85	
July	10.	Payment by State Comptroller on account	2,272 85	
	11.	Payment by State Comptroller on account	2,228 06	
	17.	Payment by State Comptroller on account	887 15	
	29.	Payment by State Comptroller on account	900 00	
Aug.	16.	Payment by State Comptroller on account	2,673 74	
	31.	Payment by State Comptroller on account	425 90	
Sept.	13.	Payment by State Comptroller on account	2,228 82	
	17.	Payment by State Comptroller on account	381 34	
				$15,203 77

Receipts of Reservation.

1900.			
Nov.	1.	Receipts for month of October	$327 90
Dec.	1.	Receipts for month of November	41 30

1901.				
Jan.	1.	Receipts for month of December	$56 75	
Feb.	1.	Receipts for month of January..	41 80	
March	1.	Receipts for month of February	529 00	
April	1.	Receipts for month of March...	191 20	
May	1.	Receipts for month of April....	88 15	
June	1.	Receipts for month of May.....	405 70	
July	1.	Receipts for month of June....	2,450 40	
Aug.	1.	Receipts for month of July.....	4,843 25	
Sept.	1.	Receipts for month of August..	6,635 55	
	30.	Receipts for month of September	6,099 40	
				$21,710 40
		Total		$174,449 92

EXPENDITURES.

Maintenance.

Abstract CXXVI.

Date.		Voucher.	Name.	Amount.
1900.				
Oct.	22.	1894..	Charles M. Dow, Commissioner's expenses......	$190 65
		1895..	Thomas P. Kingsford, Commissioner's expenses.....	194 72
	31.	1896..	Peter A. Porter, Jr., Secretary and Treasurer office expenses	13 12
		1897..	Peter A. Porter, Jr., Secretary and Treasurer salary October, 1900	83 33

Date.		Voucher.	Name.	Amount.
1900.				
Nov.	2.	1898..	Pay-roll October, 1900....	$1,882 10
		1899..	Thomas V. Welch, Superintendent's office expenses.	30 95
	12.	1900..	Pay-roll, supplemental, October, 1900	10 50
		1901..	A. J. Porter, Commissioner's expenses	3 40
	20.	1902..	William R. Davies, bridges.	13 35
	22.	1903..	Thomas V. Welch, Superintendent's office expenses.	22 90
		1904..	Niagara Falls Hydraulic Power & Mfg. Co., electric lighting	50 00
		1905..	Gazette Publishing Co., Superintendent's office expenses	3 50
		1906..	James Davy, Superintendent's office expenses.....	30 93
		1907..	P. J. Davy, plumbing.....	48 75
		1908..	P. C. Flynn & Son, iron railing, buildings	95 24
		1909..	Elderfield-Hartshorn Co., tools, buildings	19 13
Dec.	3.	1910..	Peter A. Porter, Jr., Secretary and Treasurer, salary November, 1900....	83 33
		1911..	Pay-roll, November, 1900..	1,447 37

Date.	Voucher.	Name.	Amount.	
1900.				
Dec. 13.	1912	A. J. Porter, Commissioner's expenses	$6 05	
	1913	Thomas V. Welch, Superintendent's office expenses	42 86	
				$4,272 18

Abstract CXXVII.

Date.	Voucher.	Name.	Amount.
18.	1914	Peter A. Porter, Jr., Secretary and Treasurer, traveling expenses	36 45
	1915	William S. Humbert, roads	3 94
	1916	Niagara Sand Co., roads	9 00
	1917	Elderfield-Hartshorn Co., tools, buildings	12 03
	1918	Fred Batchelor, seed	9 00
	1919	Charles S. Durkee, Superintendent's office expenses	15 00
	1920	Thomas E. McGarigle, Inclined Railway	16 42
	1921	Gazette Publishing Co., Superintendent's office expenses	4 00
	1922	Niagara Falls Hydraulic Power & Mfg. Co., electric lighting	50 00
	1923	Dean & Hoffman, roads	42 25
	1924	Thomas V. Welch, Superintendent's office expenses	45 40

Date.	Voucher.	Name.	Amount.	
1900.				
Dec. 20.	1925	William F. Wall, Inclined Railway	$64 11	
	1926	Alexander Herschel, President's office expenses	65 60	
24.	1927	Alexander J. Porter, Commissioner's expenses	17 55	
	1928	Alexander J. Porter, Commissioner's expenses	23 50	
27.	1929	George Raines, Commissioner's expenses	42 60	
31.	1930	Peter A. Porter, Jr., Secretary and Treasurer, salary December, 1900	83 33	
1901.				
Jan. 2.	1931	Pay-roll, December, 1900	1,425 25	
				$1,965 43

Abstract CXXVIII.

Date.	Voucher.	Name.	Amount.
1901.			
Jan. 9.	1932	A. J. Porter, Commissioner's expenses	$7 55
	1933	Thomas V. Welch, Superintendent's office expenses	27 86
26.	1934	Peter A. Porter, Jr., Secretary and Treasurer, office expenses	10 54
31.	1935	Peter A. Porter, Jr., Secretary and Treasurer, salary, January, 1901	83 33

Date.		Voucher.	Name.	Amount.
1901.				
Feb.	2.	1936.	Pay-roll, January, 1901	$1,417 00
	4.	1937.	Thomas V. Welch, Superintendent's office expenses	49 63
	8.	1938.	Addison Johnson, Superintendent's office expenses	7 35
		1939.	P. J. Davy, buildings	29 80
		1940.	J. H. Cook & Co., buildings	16 73
		1941.	Elderfield-Hartshorn Co., buildings, Inclined Railway	8 96
	15.	1942.	A. J. Porter, Commissioner's expenses	19 20
		1943.	Thomas V. Welch, Superintendent's office expenses	31 07
	28.	1944.	Peter A. Porter, Jr., Secretary and Treasurer, salary, February, 1901	83 33
		1945.	Peter A. Porter, Jr., Secretary and Treasurer, traveling expenses	21 85
March	2.	1946.	A. J. Porter, Commissioner's expenses	10 10
		1947.	Pay-roll, February, 1901	1,426 75
	14.	1948.	Niagara Falls Hydraulic Power & Mfg. Co., electric lighting	50 00
		1949.	Niagara Falls Hydraulic Power & Mfg. Co., electric lighting	50 00

Date.	Voucher.	Name.	Amount.	
1901.				
March 14.	1950.	Niagara Falls Hydraulic Power & Mfg. Co., electric lighting	$50 00	
	1951.	W. W. Read, ice	67 48	
	1952.	Thomas E. McGarigle, Inclined Railway	4 62	
	1953.	William S. Humbert, roads, bridges	17 64	
	1954.	Welch Coal & Wood Co., coal	83 90	
	1955.	Elderfield-Hartshorn Co., tools	4 78	
	1956.	Globe Ticket Co., Inclined Railway	45 00	
	1957.	Elderfield-Hartshorn Co., tools, Inclined Railway	10 83	
				$3,635 30

Abstract CXXIX.

Date.	Voucher.	Name.	Amount.
March 27.	1958.	Thomas V. Welch, Superintendent's office expenses	$49 79
	1959.	George Raines, Commissioner's expenses	26 06
28.	1960.	Peter A. Porter, Jr., Secretary and Treasurer, traveling expenses	20 00
	1961.	A. J. Porter, Commissioner's expenses	7 90

Date.	Voucher.	Name.	Amount.	
1901.				
April 1.	1962..	Charles M. Dow, Commissioner's expenses........	$168 07	
	1963..	Peter A. Porter, Jr., Secretary and Treasurer, salary, March, 1901............	83 33	
2.	1964..	Pay-roll, March, 1901.....	1,588 75	
				$1,943 90

Abstract CXXX.

Date.	Voucher.	Name.	Amount.
April 8.	1965..	P. J. Davy, buildings.....	$18 11
	1966..	Domenick Penders, roads.	144 30
13.	1967..	Thomas P. Kingsford, Commissioner's expenses....	162 32
May 1.	1968..	Peter A. Porter, Jr., Secretary and Treasurer, salary, April, 1901.............	83 33
2.	1969..	Pay-roll, April, 1901......	2,677 12
	1970..	Pay-roll, April, 1901, supplemental..............	18 00
3.	1971..	Thomas V. Welch, Superintendent's office expenses.	34 06
9.	1872..	A. J. Porter, Commissioner's expenses...........	9 80
13.	1973..	Peter A. Porter, Jr., Secretary and Treasurer, office expenses..............	10 00
18.	1974..	P. C. Flynn & Son, buildings..................	112 88

Date.	Voucher.	Name.	Amount.
1901.			
May 18.	1975..	P. C. Flynn & Co., buildings and bridges	$205 68
	1976..	Welch Coal and Wood Co., coal	41 25
	1977..	Charlotte Haeberle, buildings	48 86
	1978..	J. H. Cook & Co., tools	5 87
	1979..	Dobbie Foundry and Machine Co., Inclined Railway	41 69
	1980..	Elderfield-Hartshorn Co., Inclined Railway	7 38
	1981..	Elderfield-Hartshorn Co., buildings, tools, water pipes	179 11
	1982..	Niagara Falls Hydraulic Power & Mfg. Co., electric lighting	50 00
	1983..	Niagara Falls Hydraulic Power & Mfg. Co., electric lighting	50 00
	1984..	Fred Batchelor, seed	10 00
31.	1985..	Peter A. Porter, Jr., Secretary and Treasurer, salary, May, 1901	83 33
June 3.	1986..	Pay-roll, May, 1901	1,388 12
	1987..	J. H. Cook & Co., buildings	102 62

Date.	Voucher.	Name.	Amount.	
1901.				
June 3.	1988.	.Niagara Falls Hydraulic Power & Mfg. Co., electric lighting............	$50 00	
	1989.	.Gazette Publishing Co., Superintendent's office expenses	7 50	
	1990.	.P. J. Davy, plumbing.....	82 28	
	1991.	.William Young, carting...	9 69	
6.	1992.	.Thomas V. Welch, Superintendent's office expenses.	52 99	
	1993.	.Thomas V. Welch, Superintendent's office expenses.	55 96	
	1994.	.Howard H. Baker & Co., Inclined Railway........	5 50	
13.	1995.	.Milton C. Johnson & Co., Secretary and Treasurer, office expenses..........	14 00	
July 1.	1996.	.Peter A. Porter, Jr., Secretary and Treasurer, salary, June, 1901.............	83 33	
	1997.	.Pay-roll, June, 1901.......	1,117 75	
				$6,962 83

Abstract CXXXI.

July 18.	1998.	.Elderfield-Hartshorn Co., water pipes, tools, buildings....................	$78 32
	1999.	.P. C. Flynn & Son, buildings	176 50

Date.	Voucher.	Name.	Amount.
1901.			
July 18.	2000.	Gazette Publishing Co., Superintendent's office expenses	$12 50
	2001.	Rush Electric Co., Inclined Railway	7 00
	2002.	Gazette Publishing Co., Superintendent's office expenses	7 50
22.	2003.	Peter A. Porter, Jr., Secretary and Treasurer, office expenses	18 45
31.	2004.	Peter A. Porter, Jr., Secretary and Treasurer, salary, July, 1901	83 33
Aug. 2.	2005.	Pay-roll, July, 1901	1,713 25
5.	2006.	Gazette Publishing Co., Secretary and Treasurer, office expenses	7 75
7.	2007.	James Davy, Superintendent's office expenses, buildings	65 42
	2008.	Frank E. Giraux, roads	24 00
	2009.	W. A. Shepard & Co., walks	250 00
	2010.	Dean & Hoffman, walks	66 70
	2011.	F. W. Oliver Co., tools	10 67
	2012.	W. S. Humbert, walks	27 65
	2013.	Elderfield-Hartshorn Co., tools, buildings	47 44

Date.	Voucher.	Name.	Amount.
1901.			
Aug. 7.	2014..	P. C. Flynn & Son, signs, flagpole	$66 25
	2015..	Elderfield-Hartshorn Co., tools, buildings, pipes, railings, Inclined Railway.	81 92
	2016..	Thomas V. Welch, Superintendent's office expenses, roads	46 41
9.	2017..	Peter A. Porter, Jr., Secretary and Treasurer, office expenses	28 50
	2018..	Dobbie Foundry and Machine Co., drainage	22 13
	2019..	Welch Coal and Wood Co., coal	2 75
	2020..	Niagara Falls Hydraulic Power & Mfg. Co., electric lighting	3 83
	2021..	Niagara Falls Hydraulic Power & Mfg. Co., electric lighting	50 00
	2022..	Niagara Falls Hydraulic Power & Mfg. Co., electric lighting	50 00
	2023..	J. H. Cook & Co., roads	5 81
	2024..	Charlotte Haeberle, buildings	49 87
	2025..	Charlotte Haeberle, buildings	23 61

Date.	Voucher.	Name.	Amount.	
1901.				
Aug. 9.	2026	Globe Ticket Co., Inclined Railway	$66 25	
10.	2027	Pay-roll, July, 1901, supplemental	147 25	
13.	2028	Pay-roll, August, 1901, supplemental	141 00	
16.	2029	Thomas V. Welch, Superintendent's office expenses	50 25	
Sept. 4.	2030	Peter A. Porter, Jr., Secretary and Treasurer, salary, August, 1901	83 33	
	2031	A. J. Porter, Commissioner's expenses	2 50	
	2032	Pay-roll, August, 1901	1,774 12	
				$5,292 26

Abstract CXXXII.

Sept. 30.	2033	Peter A. Porter, Jr., Secretary and Treasurer, salary, September, 1901	$83 37	
	2034	Pay-roll, September, 1901	805 00	
				888 37

Payments out of $30,000, *as per chapter* 569, *Laws of* 1899.

Abstract VI—Series K.

1900.				
Oct. 31.	26	W. A. Shepard & Co., Shelter building, first estimate	$4,910 50	
Dec. 14.	27	W. A. Shepard & Co., Shelter building, second estimate	4,145 45	
				9,055 95

Abstract VII—Series K.

Date.		Voucher.	Name.	Amount.	
1900.					
Dec.	31.	28.	Gazette Publishing Co., Shelter building	$5 25	

Abstract VIII—Series K.

Date.		Voucher.	Name.	Amount.	
1901.					
Jan.	21.	29.	Breen Bros., Shelter building.	$765 00	
Feb.	7.	30.	W. A. Shepard & Co., Shelter building, third estimate	3,504 55	
					$4,269 55

Abstract IX—Series K.

Date.		Voucher.	Name.	Amount.	
April	19.	31.	W. A. Shepard & Co., Shelter building, fourth estimate	$2,569 42	
May	22.	32.	William Lansing, Shelter building	199 87	
		33.	Burleson Hardware Co., Shelter building	872 00	
					3,641 29

Abstract X—Series K.

Date.		Voucher.	Name.	Amount.	
Sept.	11.	34.	F. W. Oliver Co., Shelter building	$275 00	
		35.	Burleson Hardware Co., Shelter building	198 00	
		36.	W. A. Shepard & Co., Shelter building, final estimate	6,070 87	
		37.	Breen Bros., Shelter building.	1,608 00	
					8,151 87

Payments out of $120,000, as per chapter 420, Laws of 1900.

Abstract H—Series L.

Date.		Voucher.	Name.	Amount.
1900.				
Oct.	12.	19.	Pay-roll, September, 1900, arch bridge to Goat Island.	$264 75
	31.	20.	Edward A. Bond, arch bridge to Goat Island...........	46 09
		21.	D. S. Hollenbeck, arch bridge to Goat Island...........	20 00
		22.	D. S. Hollenbeck, arch bridge to Goat Island...........	19 29
		23.	D. S. Hollenbeck, arch bridge to Goat Island...........	78 28
		24.	D. D. Waldo, arch bridge to Goat Island.............	13 50
		25.	D. D. Waldo, arch bridge to Goat Island.............	37 25
		26.	D. D. Waldo, arch bridge to Goat Island.............	162 82
		27.	David R. Lee, arch bridge to Goat Island.............	69 37
		28.	W. H. Keepers & Co., third estimate, arch bridge to Goat Island.............	8,670 00
Nov.	12.	29.	Pay-roll, October, 1900, arch bridge to Goat Island.....	252 00
	21.	30.	W. H. Keepers & Co., fourth estimate, arch bridge to Goat Island.............	18,224 00

Date.	Voucher.	Name.	Amount.	
1900.				
Nov. 26.	31	D. D. Waldo, arch bridge to Goat Island	$259 55	
	32	David R. Lee, arch bridge to Goat Island	125 57	
	33	D. S. Hollenbeck, arch bridge to Goat Island	118 51	
	34	E. N. Allendorf, arch bridge to Goat Island	28 43	
	35	David R. Lee, arch bridge to Goat Island	10 22	
	36	R. S. Buck, arch bridge to Goat Island	515 95	
	37	Walter Jones, arch bridge to Goat Island	255 00	
	38	Walter Jones, arch bridge to Goat Island	270 00	
				$29,440 58

Abstract III—Series L.

Dec. 18.	39	Pay-roll, November, 1900, arch bridge to Goat Island	$225 00
	40	E. N. Allendorf, arch bridge to Goat Island	129 43
	41	D. S. Hollenbeck, arch bridge to Goat Island	115 71
	42	D. D. Waldo, arch bridge to to Goat Island	185 20
	43	F. W. Hamilton, arch bridge to Goat Island	101 10

Date.		Voucher.	Name.	Amount.	
1900.					
Dec.	18.	44.	Walter Jones, arch bridge to Goat Island	$275 00	
		45.	Edward A. Bond, arch bridge to Goat Island	23 55	
	24.	46.	W. H. Keepers & Co., fifth estimate, arch bridge to Goat Island	7,803 00	
	31.	47.	R. S. Buck, arch bridge to Goat Island	290 74	
		48.	E. N. Allendorf, arch bridge to Goat Island	11 86	
					$9,160 59

Abstract IV—Series L.

Date.		Voucher.	Name.	Amount.
1901.				
Jan.	18.	49.	Pay-roll, December, 1900, arch bridge to Goat Island.	$181 50
		50.	Fred W. Hamilton, arch bridge to Goat Island	68 37
		51.	D. S. Hollenbeck, arch bridge to Goat Island	119 57
		52.	Walter Jones, arch bridge to Goat Island	90 00
		53.	D. D. Waldo, arch bridge to Goat Island	192 95
Feb.	15.	54.	Pay-roll, January, 1901, arch bridge to Goat Island	186 00
		55.	D. D. Waldo, arch bridge to Goat Island	172 97

Date.	Voucher.	Name.	Amount.	
1901.				
Feb. 15.	56	D. S. Hollenbeck, arch bridge to Goat Island	$113 57	
March 14.	57	D. S. Hollenbeck, arch bridge to Goat Island	96 00	
	58	Edward A. Bond, arch bridge to Goat Island	25 15	
	59	D. D. Waldo, arch bridge to Goat Island	145 93	
	60	Pay-roll, February, 1901, arch bridge to Goat Island	168 00	
				$1,560 01
		Abstract V—Series L.		
28.	61	W. H. Keepers & Co., sixth estimate, arch bridge to Goat Island	$10,404 00	
	62	W. H. Keepers & Co., seventh estimate, arch bridge to Goat Island	1,734 00	
	63	W. H. Keepers & Co., eighth estimate, arch bridge to Goat Island	884 00	
	64	R. S. Buck, arch bridge to Goat Island	127 69	
				13,149 69
		Abstract VI—Series L.		
April 13.	65	D. D. Waldo, arch bridge to Goat Island	$184 40	
	66	D. S. Hollenbeck, arch bridge to Goat Island	107 57	

Date.	Voucher.	Name.	Amount.
1901.			
April 13.	67	Pay-roll, March, 1901, arch bridge to Goat Island....	$139 50
19.	68	W. H. Keepers & Co., ninth estimate, arch bridge to Goat Island.............	867 00
May 16.	69	W. H. Keepers & Co., tenth estimate, arch bridge to Goat Island.............	3,468 00
	70	Pay-roll, April, 1901, arch bridge to Goat Island....	135 00
	71	F. W. Hamilton, arch bridge to Goat Island...........	95 22
	72	D. S. Hollenbeck, arch bridge to Goat Island...........	103 71
	73	D. D. Waldo, arch bridge to Goat Island.............	163 07
	74	H. S. Ball, arch bridge to Goat Island.............	95 45
June 10.	75	W. H. Keepers & Co., duty, arch bridge to Goat Island.	2,615 96
	76	Pay-roll, May, 1901, arch bridge to Goat Island....	139 50
	77	D. S. Hollenbeck, arch bridge to Goat Island...........	113 57
	78	H. S. Ball, arch bridge to Goat Island.............	118 86
	79	F. W. Hamilton, arch bridge to Goat Island...........	118 86

Date.	Voucher.	Name.	Amount.	
1901.				
June 10.	80.	D. D. Waldo, arch bridge to Goat Island	$217 09	
15.	81.	W. H. Keepers & Co., eleventh estimate, arch bridge to Goat Island	7,599 00	
				$16,281 76

Abstract VII—Series L.

Date.	Voucher.	Name.	Amount.
July 10.	82.	Pay-roll, June, 1901, arch bridge to Goat Island	$142 50
11.	83.	Edward A. Bond, arch bridge to Goat Island	23 26
	84.	D. D. Waldo, arch bridge to Goat Island	121 57
	85.	D. D. Waldo, arch bridge to Goat Island	200 40
	86.	Thad. Wilson, arch bridge to Goat Island	80 16
	87.	F. W. Hamilton, arch bridge to Goat Island	128 57
	88.	A. B. Williams, arch bridge to Goat Island	25 47
	89.	J. B. Barrett, arch bridge to Goat Island	99 23
	90.	F. V. Searls, arch bridge to Goat Island	64 28
	91.	D. S. Hollenbeck, arch bridge to Goat Island	115 71

Date.	Voucher.	Name.	Amount.	
1901.				
June 25.	92	W. H. Keepers & Co., twelfth estimate, arch bridge to Goat Island	$10,132 00	
29.	93	George McDonald, arch bridge to Goat Island	23 31	
	94	R. S. Greenman, arch bridge to Goat Island	19 72	
Aug. 16.	95	R. S. Buck, arch bridge to Goat Island	203 37	
	96	D. D. Waldo, arch bridge to Goat Island	187 80	
	97	D. S. Hollenbeck, arch bridge to Goat Island	119 57	
	98	Thad. Wilson, arch bridge to Goat Island	123 64	
	99	F. W. Hamilton, arch bridge to Goat Island	80 94	
31.	100	W. H. Keepers & Co., thirteenth estimate, arch bridge to Goat Island	1,734 00	
				$13,625 50

Abstract VIII—Series L.

Sept. 13.	101	Thad. Wilson, arch bridge to Goat Island	$52 40
	102	D. D. Waldo, arch bridge to Goat Island	167 05
	103	D. S. Hollenbeck, arch bridge to Goat Island	107 57

Date.		Voucher.	Name.	Amount.	
1901.					
Sept.	30.	104.	D. D. Waldo, arch bridge to Goat Island	$44 07	
		105.	D. S. Hollenbeck, arch bridge to Goat Island	10 52	
					$381 61

Payments out of $3,000, as per chapter 420, Laws of 1900.

Abstract I—Series M.

May	16.	1.	John A. Roebling's & Sons, repairs to Sister Island bridges	$2,800 00	
June	15.	2.	Stowell & Cunningham, repairs to Sister Island bridges	4 75	
					2,804 75

Abstract II—Series M.

July	17.	3.	P. C. Flynn & Son, repairs to Sister Island bridges	$143 24	
		4.	F. W. Oliver Co., repairs to Sister Island bridges	50 50	
					193 74

Payments out of $5,000, as per chapter 419, Laws of 1900.

Abstract II—Series N.

1900.					
Oct.	12.	20.	Pay-roll, September, 1900, stone stairway, Goat Island	$548 25	
	31.	21.	F. J. Munson, stone stairway, Goat Island	31 50	

Date.		Voucher.	Name.	Amount.	
1900.					
Oct.	31.	22..	W. S. Egerton, stone stairway, Goat Island	$44 00	
		23..	R. D. Young, stone stairway, Goat Island	10 65	
Nov.	12.	24..	Pay-roll, October, 1900, stone stairway, Goat Island	141 39	
					$775 79

Payments out of $44,665.15, *as per chapter* 645, *Laws of* 1901.

Abstract I—Series O.

1901.				
June	13.	1..	Wm. F. Wall, Inclined Railway, Ext. Ex	$230 31
		2..	C. T. Middlebrook, Inclined Railway, Ext. Ex	72 00
		3..	L. B. Ackley, grass sod, Ext. Ex	338 00
		4..	Wm. A. Shepard & Co., completing and furnishing Shelter building	90 15
		5..	Wm. A. Shepard & Co., completing and furnishing Shelter building	74 60
		6..	Wm. A. Shepard & Co., completing and furnishing Shelter building	581 00
		7..	Wm. A. Shepard & Co., completing and furnishing Shelter building	69 75

Date.		Voucher.	Name.	Amount.	
1901.					
June	13.	8.	Pay-roll, May, 1901, Extraordinary expenditures	$1,555 25	
	15.	9.	Baker Art Gallery, folding map and guide, Ext. Ex.	194 85	
					$3,205 91

Abstract II—Series O.

July	10.	10.	Pay-roll, June, 1901, Extraordinary expenditures	$2,272 85
	11.	11.	City of Niagara Falls, local paving assessment	2,004 78
		12.	L. B. Ackley, grass sod, Ext. Ex	223 28
	17.	13.	Schumacher & Moyer, completing and furnishing Shelter building	70 60
		14.	Howard H. Baker & Co., completing and furnishing Shelter building	15 00
		15.	Breen Brothers, completing and furnishing Shelter building	718 00
	17.	16.	Breen Brothers, completing and furnishing Shelter building	83 55
	29.	17.	David Phillips, bridge to Terrapin Point	900 00
Aug.	16.	18.	Metal Stamping Co., completing and furnishing Shelter building	21 63

Date.	Voucher.	Name.	Amount.
1901.			
Aug. 16.	19	Clark Furnishing Co., completing and furnishing Shelter building	$21 50
	20	F. W. Oliver Co., completing and furnishing Shelter building	13 40
	21	A. Cutler & Son, completing and furnishing Shelter building	225 90
	22	Schumacher & Moyer, completing and furnishing Shelter building	14 25
	23	Burleson Hardware Co., completing and furnishing Shelter building	7 00
	24	Burleson Hardware Co., completing and furnishing Shelter building	8 00
	25	Wm. A. Shepard & Co., completing and furnishing Shelter building	42 15
	26	Wm. A. Shepard & Co., completing and furnishing Shelter building	8 60
	27	Pay-roll, July, 1901, improving ground near arch bridges	555 12
	28	Pay-roll, July, 1901, extraordinary expenditures	1,790 92

Date.		Voucher.	Name.	Amount.	
1901.					
Aug.	16.	29	Salem G. LeValley, police badges, Ext. Ex.	$6 20	
		30	The Courier Co., folding map and guide, Ext. Ex.	150 60	
		31	Dobbie Foundry and Machine Co., bridge to Terrapin Point	34 37	
	31.	32	Howard Iron Works, park seats, Ext. Ex.	200 00	
					$9,387 70

Abstract III—Series O.

Date.		Voucher.	Name.	Amount.
Sept.	13.	33	Pay-roll, August, 1901, extraordinary expenditures	$2,026 25
		34	Williams Lansing, completing and furnishing Shelter building	202 57
	17.	35	Pay-roll, September, 1901, supplemental, Ext. Ex.	26 13
		36	Globe Ticket Co., Inclined Railway, Ext. Ex.	57 50
		37	Gazette Publishing Co., printing, Ext. Ex.	9 75
		38	Gazette Publishing Co., printing, Ext. Ex.	7 50
		39	Fred J. Allen, Inclined Railway, Ext. Ex.	18 25
		40	Wm. A. Shepard & Co., completing and furnishing Shelter building	201 21

Date.	Voucher.	Name.	Amount.	
1901.				
Sept. 17.	41..	F. W. Oliver & Co., completing and furnishing Shelter building	$55 50	
	42..	Schumacher & Moyer, completing and furnishing Shelter building	5 50	
				$2,610 16

Remittance to State Treasurer.

1900.			
Nov. 5.	Draft for October receipts........	$327 90	
Dec. 1.	Draft for November receipts......	41 30	
1901.			
Jan. 2.	Draft for December receipts......	56 75	
Feb. 2.	Draft for January receipts........	41 80	
March 5.	Draft for February receipts.......	529 00	
April 2.	Draft for March receipts.........	191 20	
May 3.	Draft for April receipts...........	88 15	
June 3.	Draft for May receipts...........	405 70	
July 1.	Draft for June receipts...........	2,450 40	
Aug. 1.	Draft for July receipts...........	4,843 25	
Sept. 3.	Draft for August receipts........	6,635 55	
30.	Draft for September receipts......	6,099 40	
			21,710 40
	Cash balance on hand.....................		77 55
	Total		$174,449 92

CLASSIFICATION OF ACCOUNTS.

Maintenance.

Secretary and Treasurer, office expenses......	$102 36	
Secretary and Treasurer, salary.............	1,000 00	
Salaries, Superintendent and Clerk..........	3,300 00	
Police..............................	4,350 00	
Inclined Railway........................	2,296 65	
Prospect Park..........................	2,578 24	
Goat Island...........................	1,645 49	
Roads...............................	2,323 56	
Walks...............................	2,184 09	
Buildings............................	1,922 78	
Commissioner's expenses.................	891 97	
Superintendent's office expenses............	653 43	
Water pipes..........................	203 23	
Tools...............................	133 66	
Electric lighting.......................	503 83	
President's office expenses................	65 60	
Secretary and Treasurer, traveling expenses..	78 30	
Bridges.............................	197 60	
Coal...............................	127 90	
Ice................................	67 48	
Seed...............................	19 00	
Signs...............................	48 25	
Plumbing............................	131 03	
Iron railings..........................	81 62	
Cartage.............................	9 69	
Flag pole............................	18 00	
Railings.............................	4 38	
Drainage............................	22 13	
		$24,960 27

Improvements under chapter 569, Laws of 1899—Series K.

Shelter building		$25,123 91
Improvements under chapter 420, Laws of 1900—Series L.		
Arch bridge, mainland to Goat Island		83,599 74
Improvements under chapter 420, Laws of 1900—Series M.		
Repairing Sister Island bridges		2,998 49
Improvements under chapter 419, Laws of 1900—Series N.		
Stone stairway, Goat Island		775 79
Improvements under chapter 645, Laws of 1901—Series O.		
Inclined Railway, Ext. Ex	$488 31	
Grass sod, Ext. Ex	561 28	
Prospect Park, Ext. Ex	2,640 37	
Goat Island, Ext. Ex	1,331 86	
Folding map and guide, Ext. Ex	345 45	
Roads, Ext. Ex	734 12	
Walks, Ext. Ex	1,194 50	
Buildings, Ext. Ex	366 87	
Detectives, Ext. Ex	1,293 43	
Police badges, Ext. Ex	6 20	
Park seats, Ext. Ex	200 00	
Printing, Ext. Ex	17 25	
Improving ground near arch bridges	555 12	
Completing and furnishing Shelter building	2,529 86	
Bridge to Terrapin Point	934 37	
Local paving assessment	2,004 78	
		15,203 77
Remittances to State Treasurer		21,710 40
Cash on hand September 30, 1901		77 55
Total		$174,449 92

PETER A. PORTER, Jr.
Treasurer.

We, the undersigned, hereby certify that we have examined the foregoing report of the Treasurer for the fiscal year ended September 30, 1901, the vouchers and other papers, and we find the report and accompanying documents correct, and that the Treasurer has properly accounted for all moneys received and disbursed by him during the fiscal year ended September 30, 1901.

THOMAS P. KINGSFORD,
CHAS. M. DOW,
Commissioners of the State Reservation at Niagara.

Attest:

C. S. DURKEE,

Professional Accountant and Auditor and member of the National Association of Public Accountants, office and post-office address Room N, Arcade Building, Niagara Falls, N. Y.

Correct:

EDWARD H. PERRY.

Report of the Superintendent

OF THE

State Reservation at Niagara

FOR THE

Fiscal Year Ending September 30, 1901.

Bridge to Green Island. State Reservation at Niagara. Erected 1901.

Report of the Superintendent.

To the Commissioners of the State Reservation at Niagara:

Gentlemen.—The most important improvements made during the fiscal year ending September 30, 1901, have been the completion of the two stone arch bridges between the mainland and Goat Island; the completion of the Shelter building in Prospect Park; the construction of a new bridge from Goat Island to Terrapin Point, at the Horseshoe Falls; the renovation of the two suspension bridges to the Three Sister Islands, and the grading and filling adjacent to the new stone arch bridges.

Stone Arched Bridges, Mainland to Goat Island.

At the close of the last fiscal year the stone arched bridge from Green Island to Goat Island was completed, excepting the parapet walls and the sidewalks, while the piers only for the bridge from the mainland to Green Island were in place. The temporary wooden foot bridge between the mainland and Green Island was almost entirely swept away by the high water and floating ice during the winter months.

April 1, 1901, work upon the bridges was resumed, and the parapet walls of the bridge from Green Island to Goat Island were quickly completed. A new wooden foot bridge was built from the mainland to Green Island. Considerable delay was caused by the uncertainty concerning the floating ice from Lake Erie, which would

endanger the centers for the arches placed in the rapids between the mainland and Green Island. For the first time in many years, there was no run of ice from Lake Erie. As soon as it was considered certain that the ice would not interfere with the construction of the centers, work was commenced on the bridge from the mainland to Green Island. The last concrete arch was completed on June 29th, the bridge was opened to the public July 14th, the stone work was completed July 26th, and the sidewalks on August 24th.

The approaches to the bridges have been filled, graded and planted, the roads and walks readjusted to meet the new conditions, the water pipes to Goat Island laid in the roadbed, drains and catch basins constructed, and all traces of the work of construction removed.

Photographs of the new bridges are herewith submitted, and the contract and supplemental contract for the construction of the bridges are hereto appended.

Suspension Bridges to Three Sister Islands.

The repairs of the two suspension bridges to the Three Sister Islands were completed on May 9th by the John A. Roebling's Sons Company of New York. New cables, anchors, metal needle beams and braces were provided.

The woodwork of the bridges was repaired and the bridges painted; the stairs at the approaches to the bridges were removed and inclined walks of rustic stone and gravel substituted, which are safe and convenient and more natural in appearance.

The suspension bridges bore the heavy traffic of the past season without any apparent strain.

Bridge to Terrapin Point.

The wooden bridge from Goat Island to Terrapin Point was removed during the spring months, and a new bridge of steel and iron, with plank floor, constructed.

The bridge to Luna Island has been repainted, and the retaining walls at the rustic bridge over the overflow on the riverway repaired.

The Shelter Building.

The new Shelter building on the riverway, in Prospect Park, was completed and opened to the public on July 4th. It contains spacious rooms for the accommodation of visitors, the offices of administration, toilet rooms and storerooms. The windows in the basement story have been enlarged and the two large end rooms finished, the completion of which was not included in the original contract.

A large amount of filling, grading and sodding has been done around the Shelter building, gravel walks constructed, and a stone walk, ten feet wide, laid from the Shelter building to the riverway. The old open frame pavilion, immediately adjacent to the new Shelter building in Prospect Park, has been removed.

Cave of the Winds Building.

The Cave of the Winds building on Goat Island has been moved eastward across the road to a less conspicuous place, where it does not obstruct the view of the Falls and the river. The location formerly occupied has been filled, iron guard railings, stairways and gates constructed, and repairs made upon the Biddle stairs leading to the Cave of the Winds.

The Cave of the Winds building has been repainted and a veranda constructed for the accommodation and shelter of visitors.

One of the buildings used for drying clothes was destroyed by fire. The prompt and energetic action of the city fire department prevented the flames from spreading. The building was rebuilt by the lessee of the Cave of the Winds.

Inclined Railway Building.

The frame structure covering the Inclined Railway is old and should be renewed. Many of the sills and other timbers have been renewed during the past year. The weight of snow and ice upon the structure during the winter months is very great. In April, the gable on the south side was torn off by sliding ice. The damage was repaired, the building painted, the flume and the machinery in the wheelpit repaired, the cars renovated, a new cable attached to the cars, a new ticket office provided, and everything made ready for the great multitude of visitors from the Pan-American Exposition in Buffalo.

Roads.

The Paving of Buffalo avenue adjacent to the Reservation made it necessary to widen and raise the grade of First street, between Buffalo avenue and the riverway.

The road around the head of Goat Island from the entrance to the Three Sister Islands was much worn and in need of repairs. An opportunity occurred for obtaining a large quantity of gravel from an excavation, for building purposes, at a cost of 10 cents per load. With the gravel so obtained, the roads on Goat Island, Prospect Park and on the riverway were extensively repaired and put in order for the heavy traffic of the Pan-American Exposition year.

Walks.

The wooden stairs at the right at the entrance to Goat Island have been removed and a winding, inclined, gravel walk constructed to the top of the bank.

A winding, inclined walk has also been constructed on the left of the entrance to Goat Island, and the flat, artificial spaces on either side of the road, at the approach to Goat Island, filled and graded, and large boulders placed at the approaches to the new stone arched bridges. The graded banks were covered with sod and planted with shrubs and vines.

The upper half of the stairway at the Horseshoe Falls on Goat Island was removed and an inclined, gravel walk with rustic stone embankments constructed, making the descent more safe and natural. The large amount of filling done on Green Island at the approaches to the new stone arched bridges made it necessary to rebuild the gravel walks on either side of the road, the entire width of the island. Repairs were also made upon the gravel walks along the riverway.

Grading and Filling.

The completion of the new stone arched bridges, in August, found the grounds at Bridge street and on Green Island in great disorder and greatly damaged by the work of construction. The damaged portions of the grounds were repaired and seeded down, the approaches to the bridges covered with sod and planted with shrubs and vines; the roadway on Green Island was filled to the grade of the new bridges and the surface of the island cultivated and seeded down. The paving of Buffalo avenue adjacent to the Reservation at Port Day necessitated a large amount of filling and grading. The river shore at "The Wing" below Fourth street was riprapped with large stones and filled and graded.

Two landslides in Prospect Park and on Goat Island necessitated the filling of the cavities and the removal of the iron guard railing further back from the edge of the high bank.

Planting.

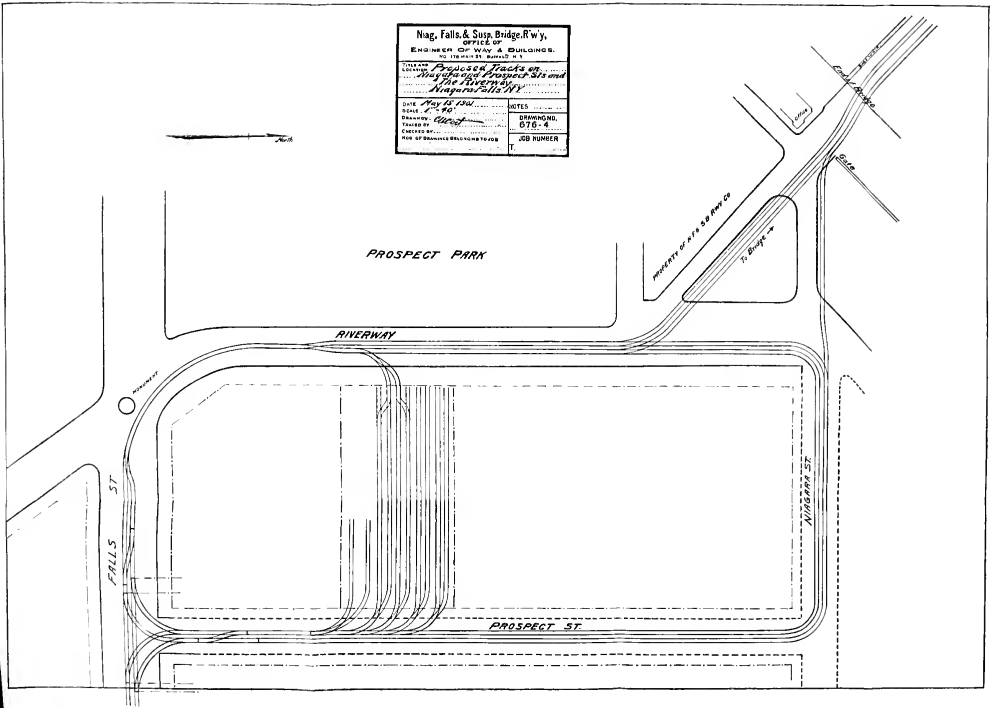
A number of trees have been planted in Prospect Park to take the place of old trees which have died out. Vines and drooping shrubs have been planted at the new stone stairway on Goat Island, at the new walks, at the approaches to Goat Island, at the approaches to the new stone arched bridges, and at the rustic bridges on Riverway. Vines have also been planted about the walls of the new Shelter building. The stock in the nursery has been cultivated, the plantations of shrubbery pruned, and a large amount of compost collected for spreading upon the lawns during the winter season.

The Ponds.

In order to insure an adequate supply of water for the operation of the Inclined Railway during the Pan-American Exposition, the water was shut off from the pond in Prospect Park, used as a reservoir, the growth of eel-grass removed, and the pond deepened. A wing of the pond in which the water was stagnant was filled, covered with sod. The basin of the fountain in Prospect Park was removed and the site filled and covered with sod. The eel-grass was also removed from the pond at the loop at Port Day, the work requiring a flat boat and a crew of four men more than a month for its performance.

The Electric Railway in the Riverway.

The station of the Electric Railway Company, on the east side of the riverway, has been completed. A double track has been laid in the riverway from Niagara street to the entrance to the steel arch



Niag. Falls. & Susp. Bridge. R'w'y,
OFFICE OF
ENGINEER OF WAY & BUILDINGS.
NO 178 MAIN ST. BUFFALO N Y
TITLE AND LOCATION Proposed Tracks on Niagara and Prospect Sts and The Riverway Niagara Falls NY
DATE May 15 1901
SCALE 1" = 40'
DRAWN BY
TRACED BY
CHECKED BY
NOS OF DRAWINGS BELONGING TO JOB
NOTES
DRAWING NO. 676-4
JOB NUMBER
T.
North
PROSPECT PARK
PROPERTY OF N F & S B RWY CO
To Bridge →
Office
Gate
RIVERWAY
MONUMENT
FALLS ST
NIAGARA ST.
PROSPECT ST.

bridge, and a second track in the riverway from the entrance to the steel arch bridge to the electric railway station, the street having been widened for that purpose, according to the agreement with the Electric Railway Company.

Before the completion of the railway station, the attention of the railway company was called by the Superintendent to the unnecessary blocking of the sidewalks by cars, the dangerous speed of cars at times, and the usage of the riverway by the company as a terminus and standing place for cars, in violation of the agreement. Since the completion of the railway station, some of the causes for complaint have been remedied, but there is still a tendency on the part of the company to have cars stand upon the riverway longer than is necessary. During the Pan-American Exposition as many as fifteen thousand visitors came from Buffalo and returned by the electric railway in one day. Aside from the frequent overcrowding of the cars, the service was excellent and a great convenience and accommodation to the public. Notwithstanding the tracks in the riverway, visitors on arrival were unloaded at the corner of Falls and Prospect streets, the headquarters of many confidence men and gamblers, where the lack of order and protection to visitors gave rise to many serious causes for complaint. Visitors should be brought by the railway company to the railway station and to the State Reservation as agreed, otherwise the object of the Commissioners in granting a revocable license to the railway company in the riverway will be defeated, in which case it seems questionable whether the railway company should be allowed to use the tracks in the riverway, which are owned by the State.

Reservation Carriage Service.

Until the completion of the stone arched bridges, the Reservation carriage service was operated by placing horses and carriages on Goat Island.

The multitude of visitors from the Pan-American Exposition made it necessary for the lessee to procure a large additional number of carriages. Even with such additional facilities, it was difficult to transport the number of visitors to the Reservation. The service was operated during the year without accident or complaint.

Licensed Carriage Drivers.

During the year no public carriage stands have been allowed upon the Reservation. Very little difficulty is experienced with the majority of the carriage drivers, especially those who own their carriages and are disposed to be courteous and accommodating to visitors. But many improper persons are licensed as carriage drivers by the city government, which gives rise to constant cause for complaint. Several of these have been discovered acting in collusion with gamblers and confidence men, brought here by the Pan-American Exposition. During the year eight licensed carriage drivers have been excluded from the Reservation for violation of the ordinances.

The Cave of the Winds.

Notwithstanding the change in the location of the Cave of the Winds building during the Pan-American year, the Cave of the Winds was visited by the greatest number of people of any year since it has been operated as a point of interest. The general question whether the State should any longer allow visitors to be encouraged to pass through the Cave of the Winds is respectfully submitted to the Commissioners for consideration.

Shelter Building. State Reservation at Niagara. Erected 1901.

This is entirely aside from the matter of the Biddle stairs, forming the mode of access to the Cave, which are old and unsuitable. Many arguments can be adduced against submitting visitors to this tiresome and hazardous undertaking. The removal of the dressing rooms, dry house and clothes yard, and the discontinuance of the business, would be in keeping with the work of the State, in restoring the grounds about the Falls, so far as possible, to a natural condition.

Steamboat Landing.

During the year the steamboat landing has been kept in repair by the Maid of the Mist Steamboat Company. Two boats were in operation during the season, which, because of the Pan-American Exposition, was greatly advantageous to the steamboat company.

Inspection by Governor Odell and Party.

On September 27th the State Reservation was visited and the new bridges, Shelter building and other improvements inspected by Governor Odell, Senator Ellsworth, Presiment *pro tem.* of the Senate; Senator Higgins, Chairman of the Finance Committee of the Senate; Assemblyman Allds, Chairman of the Ways and Means Committee of the Assembly, and other State officers.

President McKinley and Party.

On September 6th the State Reservation was visited by President McKinley and party, three hours previous to the assassination of the President at the Pan-American Exposition in Buffalo.

The President expressed deep interest in the restoration of tne grounds about the Falls, and said that the State of New York was doing a good work at Niagara.

The Pan-American Exposition Visitors.

The Pan-American Exposition brought a great number of visitors to the Reservation, the estimated attendance reaching as high as fifty thousand visitors in one day. On several occasions it was necessary to discontinue the sale of tickets at the Inclined Railway because of the inability to carry the number of persons seeking transportation. The increased number of visitors necessitated the employment of a large additional number of laborers and caretakers. Extra precautions were taken to insure the safety of all bridges, stairways, railings and observation points in the Reservation, and to prevent disorder or accident of any kind.

Notwithstanding the work upon the bridges over the rapids, the many dangerous places in the Reservation, and the unprecedented number of visitors, no disorder or accident of any kind occurred.

Gamblers and Confidence Men.

The Pan-American Exposition brought to the Reservation a large number of gamblers and confidence men. The method of operation of the confidence men was to engage a promising stranger in conversation and induce him to accompany them to some resort up town where "souvenirs of Niagara" or "tickets to points of interest" were to be obtained gratis. On their arrival at the place, confederates appeared and a trap was sprung to induce the stranger to take part in "three card monte" and similar games. In many cases unwary strangers were fleeced in this manner.

The resorts and the operations carried on in them were well known to the police department of the city and to the city authorities. In many cases, in which the injured party reported the facts to the Superintendent of the Reservation, complaint was made to the city police headquarters, where the victims were informed that nothing

could be done for them. In one case the confidence men had secured a draft for $200, which they forwarded for collection through the regular channels, endorsed by a local "politician" and proprietor of a resort for gamblers and confidence men, but payment was stopped by advice of the Reservation officers. In another case an aged Western farmer barely escaped robbery of a draft for $2,000, the proceeds of the sale of his farm and the earnings of his lifetime.

In still another case, a stranger notified a Reservation officer that he had been approached by a confidence man and invited to take part in a well-known confidence game. When the officer ordered the offender to leave the Reservation, he informed the officer that he was a friend of the alderman of the First ward of the city, whom he named, and for that reason expected to escape molestation. Among the swindlers who infested the grounds were four women, well known to the police officers of the city.

The frequency of these complaints caused the Superintendent to place in the hands of the Reservation officers notices for distribution to visitors, of which the following is a copy:

CAUTION TO VISITORS!

BEWARE OF "CONFIDENCE MEN" AND PICKPOCKETS!

DO NOT BE ENTICED ANYWHERE BY STRANGERS, WHO MAY BE "SHARPERS!"

PLEASE REPORT ANY ATTEMPT TO SWINDLE YOU AT ONCE TO THE RESERVATION OFFICERS.

T. V. WELCH,

Superintendent State Reservation at Niagara.

After the notice to the public of their presence and the exposure of their operations the confidence men disappeared, but came again from time to time during the season, seemingly upon the suggestion of persons here who controlled their operations in this locality.

The Pan-American Exposition also brought to the border of the Reservation, on the eastern side of the riverway, a number of fakirs' immoral and disgusting exhibitions, and gambling places evidently organized and controlled in the same manner as the operations of the confidence men. Buildings on the eastern border of the Reservation were rented, and several vacant lots adjacent to the Reservation were leased and temporary structures erected on them by an "Amusement Company" licensed by the city of Niagara Falls. These "places of amusement" were called "The Midway," "Congress Museum," "Saints and Sinners," "Streets of Asia," "Pan-American Beauties," "Amusement Parlor" and other names, the names being changed from time to time.

In these places degrading and immoral exhibitions were licensed by the city authorities, and attempts to revoke the licenses of the most brutal and vicious were defeated by an element in the common council, in harmony with the existing state of affairs. Several of these so-called "places of amusement" were, in reality, gambling places of the worst character, into which unsuspecting strangers were enticed by swarms of "Cappers," systematically swindled, and in some cases violently robbed of their money. Daily complaints were made at the office of the Reservation Superintendent by the victims, in many cases left penniless long distances from their homes. In some cases the whole or part of the money was recovered, the city police acting as go-betweens in the transactions, but no steps were taken by the city police department to punish the offenders or to close the unlawful resorts until the season was over.

In one case, in which the Reservation Superintendent brought to the mayor a stranger from Nova Scotia who had been swindled out of $100, all the money in his possession, in one of these gambling places said to be owned by a city alderman, the mayor sent for the chief of police and ordered him to recover the money and to forthwith close the place where the offence was committed. The place was not closed and was in daily operation thereafter, showing that the chief of police did not obey the order of the mayor, or the mayor and chief of police were not acting in good faith. Complaints were made by persons swindled to the mayor, the police justice, the chief of police and to the patrolmen, but no action was taken, and in some cases the victims complaining were threatened with arrest.

Visitors seated in Prospect Park were obliged to see the exhibition of "Dancing Women," and to witness the operations of professional "Cappers" for gambling places of the worst character, and their enjoyment of the Reservation was disturbed, even on Sunday, by the noises and outcries made to attract the attention of those passing by.

Under such circumstances, although the gambling places were not within the Reservation, but under the control of the city authorities, the Superintendent of the Reservation placed an officer at the boundary of the Reservation, in front of each resort, with instructions to hand to each stranger entering the resorts a notice of warning, of which the following is a copy:

CAUTION TO VISITORS!

BEWARE OF SO-CALLED "PLACES OF AMUSEMENT" WHERE GAMBLING GAMES AND OTHER SWINDLES ARE CONDUCTED!

DO NOT BE ENTICED BY GAMBLERS OR "CAPPERS" TO TAKE PART IN ANY GAMBLING GAME!

T. V. WELCH,
Superintendent State Reservation at Niagara.

As directed at the meeting of the Commissioners held July 2d, the Superintendent transmitted to the mayor copies of the resolution of the Board and the report of the Superintendent relating to the unlawful exhibitions, licensed by the city, adjacent to the Reservation. So far as known, no action was taken by the mayor upon the protest of the Board. The gambling places remained open until the season was over, when the last of them, "The Streets of Asia," which was known to be about to close its doors, was closed with a great show of authority by a city police sergeant and a squad of policemen in a manner that under the circumstances was farcical in the extreme and which only added to the already great disrepute of the police department of the city.

Only a small number of the cases of swindling which occurred were reported to the Reservation officers.

The evils existing in the neighborhood of the Cataract before the establishment of the State Reservation were more annoying to visitors, but were never so degrading and objectionable as these licensed by the city authorities in the immediate vicinity of the Falls during the past year. Aside from the injuries to individuals

and to public morals, they operated to destroy the quiet and peaceful enjoyment of the scenery of the Cataract, which was the object of the State in establishing the Reservation.

The primary responsibility for the present discreditable condition of affairs rests with the citizens of the city of Niagara Falls, who elected the mayor of the city. The direct responsibility rests upon the mayor, who is charged with the enforcement of the laws. In order to fix the responsibility, the city charter was amended so as to confer upon the mayor the absolute power of appointment of the city boards. The mayor appointed the board of police commissioners, of which he is the president. The responsibility for the present scandalous attempt to nullify and defeat the labor and expenditure of the State of New York in establishing the State Reservation at Niagara therefore rests upon the mayor of the city of Niagara Falls, and I respectfully submit the matter to the consideration of the Commissioners for such action as may be deemed proper.

Visitors.

The number of persons who visited the Reservation during the year is estimated at three millions. During the Pan-American Exposition, from May 20th until November 1st, the number of visitors ranged from ten thousand to fifty thousand each day. The new stone arched bridges were completed in time to accommodate the great multitudes of visitors in July, August, September and October. The care for the property of the State, the spirit of order and refinement pervading the moving masses of humanity, is a gatifying memory of the multitudes attracted to Niagara by the Pan-American Exposition.

Employees.

The number of regularly classified employees is ten—1 superintendent, 1 treasurer and secretary, 1 clerk, 1 police superintendent, 2 police and caretakers on the Islands, 3 police and caretakers in Prospect Park, 1 Inclined Railway operator.

During the Pan-American Exposition 10 additional police were employed, and a large number of additional laborers and teamsters were engaged in keeping the grounds, roads, walks, bridges and stairways in order. Of the $20,000 appropriated for extraordinary expenditure during the Pan-American Exposition, $6,364.27 remains unexpended. A statement of the number of laborers and teamsters employed each month is herewith submitted.

Statement of Number of Employees.

1900.	Foreman.	Ass't foreman.	Teamsters.	Laborers.	Maintenance.
October	1	3	2	27	
November	1	1	2	13	
December	1	1	1	13	
1901.					
January	1	1	1	13	
February	1	2	1	13	
March	1	2	1	14	
April	1	2	6	54	
May	....	......	......	20	
June	....	......	......	12	
July	....	1	......	26	
August	....	2	1	32	
September	....	......	......	3	
		Chapter 419, Laws 1900.			
1900.					
October	....	1	1		8 Carriage turnouts (Goat Island).

In the woods on Goat Island.

Chapter 420, Laws 1900.

1900.	Foremen.	Ass't. Foremen.	Teamsters.	Laborers.	Maintenance.
October	....	......	......	5	
November	....	......	......	5	
December	....	......	......	5	
1901.					
January	....	......	......	4	Arch bridges—Mainland to Goat Island.
February	....	......	......	4	
March	.....	......	......	3	
April	....	......	......	3	
May	....	......	......	3	
June	....	......	......	3	

Chapter 645, Laws 1901.

1901.	Foremen.	Ass't. Foremen.	Teamsters.	Laborers.	Maintenance.
May	1	4	5	29	
June	1	3	3	57	Care and maintenance Pan-American.
July	1	1	2	27	
August	1	2	3	30	
September	1	4	2	49	

Chapter 645, Laws 1901.

1901.	Foremen.	Ass't. Foremen.	Teamsters.	Laborers.	Maintenance.
July	....	2	2	10	Grading, filling and putting in order grounds adjacent to stone arched bridges.

Water Supply.

Plans and estimates for a water supply for the Reservation grounds and buildings have been obtained, but owing to the work upon the stone arched bridges, and the great multitudes of visitors from the Pan-American Exposition, the work of installing a system of water mains has been deferred until the coming spring.

Electric Lighting.

A plan and estimate for a lighting system for the Reservation grounds has been obtained. The estimated cost of the system is over $18,000.

This work may be done during the coming spring if an adequate appropriation is obtained.

Receipts.

The receipts by the Superintendent during the fiscal year were as follows:

From the Inclined Railway	$19,660 40
From lease of the Cave of the Winds	1,200 00
From lease of the Steamboat landing	750 00
From lease of Reservation carriage service	100 00
Total	$21,710 40

The amount received has been paid into the treasury of the State of New York.

Detailed statements of the receipts and expenditures by the Superintendent, the amount of the pay-rolls for each month, and the classification of the pay-rolls and accounts are hereto appended.

Respectfully submitted,

THOMAS V. WELCH,

Superintendent.

Contracts and Specifications

FOR

Stone Arched Bridges from Mainland to Goat Island, State Reservation at Niagara.

Erected 1901.

Contracts and Specifications.

By Authority of Chapters 419 and 420 of the Laws of 1900, State of New York.

THIS AGREEMENT, made this twenty-third day of June, in the year nineteen hundred, by and between William H. Keepers, James H. Wynkoop and John M. Braly, composing the firm of W. H. Keepers and Company, of the city of New York, in the State of New York, party of the first part, and hereinafter called the contractor, and the People of the State of New York, by Andrew H. Green, George Raines, Charles M. Dow, Thomas P. Kingsford and Alexander J. Porter, composing the Commissioners of the State Reservation at Niagara, of the second part.

WITNESSETH, That the said contractor has agreed, and by these presents does agree, for and in consideration of the covenants and payments to be made as hereinafter provided for, to furnish all of the materials, appliances, tools and labor required and build and complete, in the most substantial and workmanlike manner, a concrete-steel arch bridge with stone facing, gravel roadway and granitoid sidewalks, extending across the Niagara River, from the mainland to Green Island, in the Niagara State Reservation, and a concrete-steel arch bridge with stone facing, gravel roadway and granitoid sidewalks across the Niagara River, from Green Island to Goat Island, in the Niagara State Reservation. Each of said bridges to consist of three spans, with radius of arch to be approved

by State Engineer: Each bridge to have a twenty-foot roadway and two ten-foot sidewalks. The bridges generally to be in accordance with the plans exhibited at the office of Andrew H. Green June 16, 1900, which have been marked for identification and are hereby referred to and made a part of this agreement.

The said contractor agrees to execute the above-described work for the sum of one hundred and two thousand and seventy dollars ($102,070) lawful money, to be paid in the manner hereinafter described; and for the further consideration of the right to use the existing bridges, abutments and piers or such materials contained therein as may be suitable, in the execution of said work; and the right to dispose of any part of said existing bridges or said material therein contained which shall not be used in the execution of said work for their own use and benefit.

The said work shall be done in conformity with the plans and specifications which are hereby referred to and made a part of this agreement, which plans and specifications shall be approved by the State Engineer and Surveyor.

The contractor further agrees to conform to the provisions of chapters 415 of the Laws of 1897, 444 of the Laws of 1897, and 567 of the Laws of 1899, relative to the Labor Law and the assignment and subletting of contracts.

The contractor further agrees to comply with the laws providing that no laborer, workman or mechanic in the employ of the contractor, or of any subcontractor, or any other person doing or contracting to do a whole or a part of the work contemplated by these specifications and this contract, shall be permitted or required to work more than eight hours in any one calendar day; except in cases of extraordinary emergency, caused by fire, flood or danger to life or property.

It is further provided that each such laborer, workman or mechanic employed by such contractor, subcontractor or other person on, about or upon such work shall receive not less than the prevailing rate of wages for a day's work in the same trade or occupation in the locality within the State where such labor is performed, or where such public works on, about or in connection with which such labor is performed in its final or completed form is to be situated, erected or used. It is further provided that any contract shall be void and of no effect unless the person or corporation making or performing the same shall comply with the provisions of section 3 of the "Labor Law," as amended by chapter 567 of the Laws of 1899, and chapter 298 of the Laws of 1900.

The contractor further agrees that he will promptly begin the work herein embraced and so prosecute the same that it shall be entirely completed on or before January 1, 1901.

It is further mutually agreed that if at any time during the prosecution of the work the contractor has, in the judgment of the State Engineer, failed to provide such men, labor, tools, appliances or materials as will ensure the completion of the said work on or before the said first day of January, nineteen hundred and one, and after ten days' notice in writing from the State Engineer (a copy of which notice shall also at the same time be sent by mail to the bondsmen of said contractor) still fails to provide such men, labor, tools, appliances or materials, then the said Commissioners may order and supply such men, labor, tools, appliances or materials at the contractor's expense and provide in their discretion for the payment of the same from any moneys due or to become due under this contract, and in case such expense shall exceed the amount due or to become due the contractor, on the final completion of the work

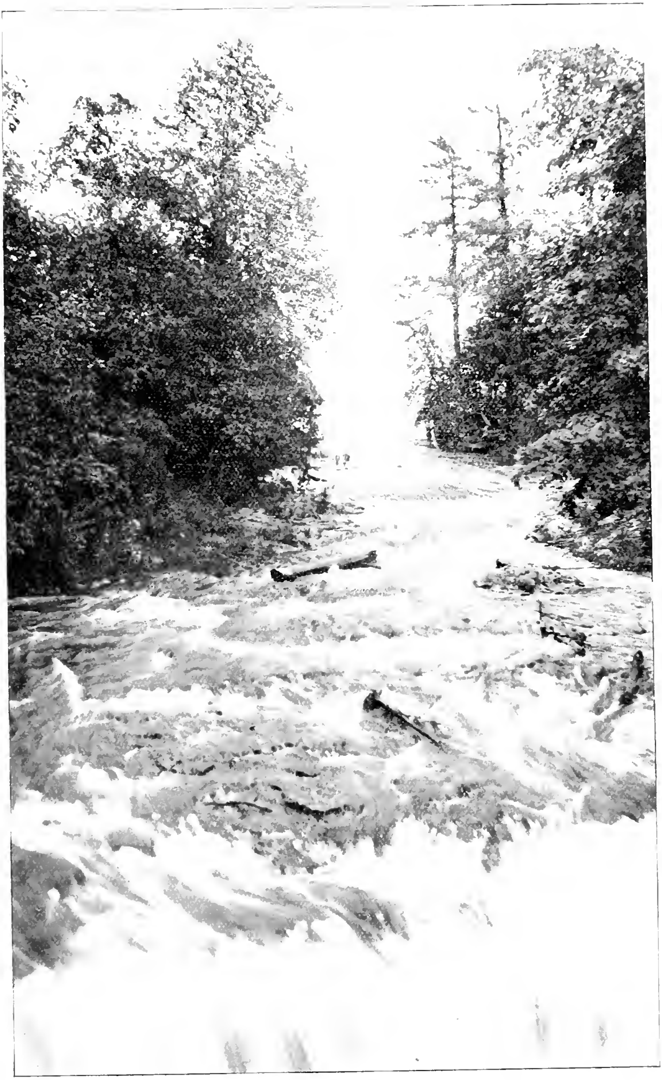
herein embraced, then it is expressly understood and agreed that the said contractor shall be personally liable for such excess.

It is further mutually agreed that no change shall be made in the plans or specifications, except by means of a supplemental agreement, to be in writing and signed by the State Engineer, the contractor and each of the said Commissioners.

It is further mutually agreed that upon the completion of the work and before the payment of the final estimate, the contractor shall furnish a guarantee for a term of five (5) years, to be of form approved by the said Commissioners.

On the faithful performance of the work herein embraced as set forth in the foregoing contract and the accompanying specifications and plans, which are a part thereof, the said Commissioners of the State Reservation above named hereby agree to use and dispose of said existing bridges and the materials therein contained as hereinbefore fully set forth, and agree to pay to the contractor the sum of one hundred and two thousand and seventy dollars ($102,070) in the following manner, to wit:

On or before the fifteenth day of each month the proportionate value, to be determined by the State Engineer, of all work done up to the first of that month, reserving fifteen per cent. (15%) thereof until the final completion, the balance to be paid within thirty days of the final completion of the work and its acceptance by the said Commissioners and the State Engineer; provided, however, that the contractor shall have given the said Commissioners such reasonable assurance as they may require that all bills connected with this work which might constitute a claim against the said Commissioners have been paid; and provided, also, that the contractor shall, if required, execute a bond with sufficient sureties and in form and amount



Hermit's Cascade, Goat Island.

satisfactory to said Commissioners for the protection of the State from such claims.

Witness our hands and seal on the day and year first above written.

W. H KEEPERS & CO.,

Party of the First Part,

By John M. Braly.

The People of the State of New York by

ANDREW H. GREEN,

THOMAS P. KINGSFORD,

CHARLES M. DOW,

GEORGE RAINES,

ALEXANDER J. PORTER,

Commissioners of the State Reservation at Niagara.

Approved June 23, 1900.

Edward A. Bond,

State Engineer and Surveyor.

State of Massachusetts, } *ss.:*
County of Worcester, }

On this 7th day of July, 1900, before me personally appeared Andrew H. Green, one of the Commissioners of the State Reservation at Niagara, to me known to be the person described in and who executed the foregoing instrument and acknowledged that he executed the same as such Commissioner.

[Notary Seal.] WILLIAM W. MACOMBER,

Notary Public.

State of New York, } ss.:
County of Monroe, }

On this 30th day of June, 1900, before me personally appeared George Raines, one of the Commissioners of the State Reservation at Niagara, to me known to be the person described in and who executed the foregoing instrument and acknowledged that he executed the same as such Commissioner.

[Notary Seal.] EDWARD R. FOREMAN,

Notary Public.

State of New York, } ss.:
County of Chautauqua, }

On this 27th day of June, 1900, before me personally appeared Charles M. Dow, one of the Commissioners of the State Reservation at Niagara, to me known to be the person described in and who executed the foregoing instrument and acknowledged that he executed the same as such Commissioner.

[Notary Seal.] MABLE S. HARMON,

Notary Public.

State of New York, } ss.:
County of Oswego, }

On this 2d day of July, 1900, before me personally appeared Thomas P. Kingsford, one of the Commissioners of the State Reservation at Niagara, to me known to be the person described in and who executed the foregoing instrument and acknowledged that he executed the same as such Commissioner.

[Notary Seal.] CHARLES A. BENTLEY,

Notary Public.

STATE OF NEW YORK, }
County of Niagara, } *ss.:*

On this 26th day of June, 1900, before me personally appeared Alexander J. Porter, one of the Commissioners of the State Reservation at Niagara, to me known to be the person described in and who executed the foregoing instrument and acknowledged that he executed the same as such Commissioner.

[Notary Seal.] F. J. COE,

Notary Public.

STATE OF NEW YORK, }
County of New York, } *ss.:*

On this 23d day of June, 1900, before me personally appeared John M. Braly, of the firm of W. H. Keepers & Co., described in and who executed the foregoing instrument and who acknowledged that he executed the same as a member and on behalf of the said firm of W. H. Keepers & Co.

[Notary Seal.] HENRY S. GREENBERGH,

Notary Public, New York County, No. 75.

GUARANTEE.—We the undersigned members of the firm of W. H. Keepers & Co., contractor for the construction of the within described bridges, hereby guarantee that the said bridges shall be free from any change of form, or any failure of the whole or any part thereof due to defects or imperfections of material or of workman-

ship, for a period of five (5) years from the final completion of said bridges and their acceptance by the State Engineer as herein provided. Said guarantee being given in consideration of the price of $102,070 herein named.

WILLIAM H. KEEPERS,
JAS. H. WYNKOOP,
JOHN M. BRALY,

Parties of the First Part.

Approved:

ANDREW H. GREEN,
THOMAS P. KINGSFORD,
CHAS. M. DOW,
GEO. RAINES,
ALEXANDER J. PORTER,

Commissioners of the State Reservation at Niagara.

COPY OF BOND.

(Original filed with contract in Comptroller's office August 4, 1900.)

Know all men by these presents, That we, William H. Keepers, James H. Wynkoop and John M. Braly, of the city of New York, in the county of New York, are held and firmly bound unto the People of the State of New York, in the sum of ($15,000) fifteen thousand dollars, to be paid to the said People: For which payment well and truly to be made, we bind ourselves, our and each of our heirs, executors and administrators, jointly and severally, firmly by these presents.

Sealed with our seals. Dated this thirty-first day of July, in the year nineteen hundred.

The condition of this obligation is such, That if the said William H. Keepers, James H. Wynkoop and John M. Braly, who have executed the five-year guarantee attached to a contract dated June 23, 1900, between said William H. Keepers, James H. Wynkoop, John M. Braly and the Commissioners of the State Reservation at Niagara, which said guarantee is attached to said contract and has been approved by said Commissioners shall in all respects well and faithfully execute and perform conditions of said guarantee then this obligation to be void, otherwise to remain in full force and virtue.

WILLIAM H. KEEPERS,
JAMES H. WYNKOOP,
JOHN M. BRALY.

STATE OF NEW YORK, }
New York County, } *ss.:*

On this 1st day of August, 1900, before me appeared James H. Wynkoop and John M. Braly, of New York city, who severally acknowledged that they executed the within instrument, and I certify that I know the persons who made the said acknowledgment to be the individuals described in and who executed the said instrument.

[Seal.] HENRY S. GREENBERGH,

Notary Public, New York County, No. 75.

STATE OF NEW YORK, }
Albany County, } ss.:

On this 31st day of July, 1900, before me appeared William H. Keepers, of New York city, who acknowledged that he executed the within instrument, and I certify that I know him to be the individual described in and who executed the said instrument.

[Seal.] JOHN J. ALLEN,
Notary Public, Rensselaer County.

Certificate filed in Albany county.

STATE OF NEW YORK, }
Albany County, } ss.:

William H. Keepers, of New York city, one of the persons named in the within bond, being duly and severally sworn, says that he is worth the sum of fifteen thousand dollars over and above all debts and liabilities entered into or incurred.

WILLIAM H. KEEPERS.

Subscribed to and sworn before me
this 31st day of July, 1900.

[Seal.] JOHN J. ALLEN,
Notary Public, Rensselaer County.

Certificate filed in Albany county.

STATE OF NEW YORK, }
New York County, } ss.:

James H. Wynkoop and John M. Braly, both of the city of New York, who have executed the within bond, being duly and severally sworn, each for himself, says that he is worth the sum set opposite

his name over and above all debts and liabilities entered into or incurred, to wit:

James H. Wynkoop, fifteen thousand dollars.

John M. Braly, seven thousand five hundred dollars.

JAS. H. WYNKOOP,
JOHN M. BRALY.

Subscribed to and sworn before me
this 1st day of August, 1900.

[Seal.] HENRY S. GREENBERGH,
Notary Public, New York County, No. 75.

COPY OF BOND.

(The original is attached to contract filed in Comptroller's office August 4, 1900.)

Revenue stamps for $2.42 attached to original.

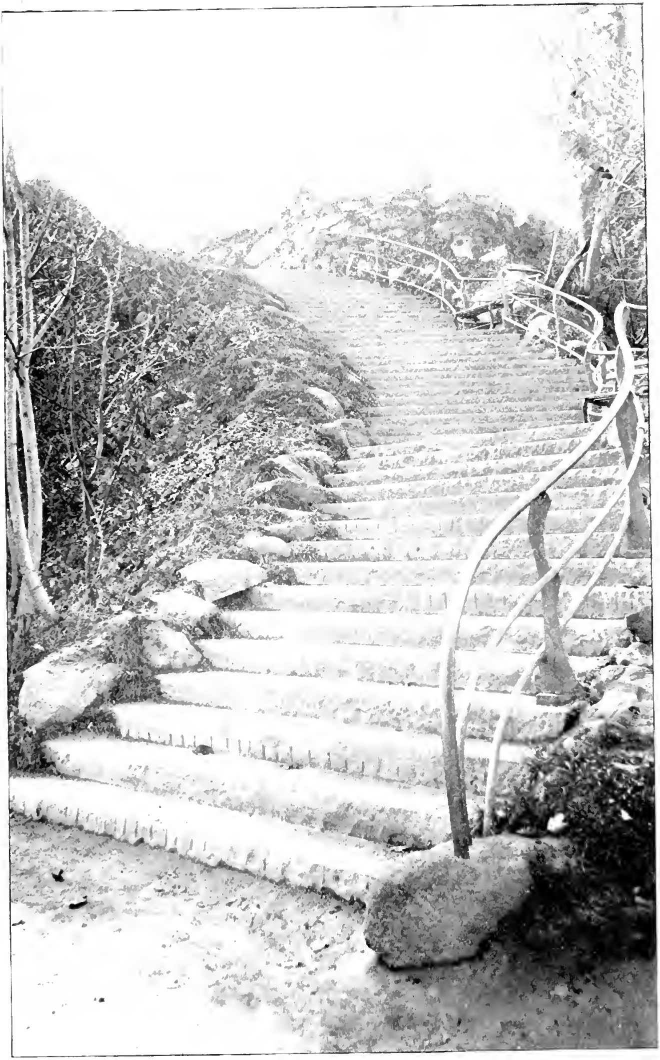
BOND.

Know all men by these presents, That we, William H. Keepers, James H. Wynkoop and John M. Braly, composing the firm of W. H. Keepers & Company of the city of New York, in the State of New York (hereinafter called the "Principal"), and the United States Fidelity and Guaranty Company, a corporation organized under the Laws of Maryland (hereinafter called the "Surety"), are held and firmly bound unto the People of the State of New York in the full and just sum of fifty-one thousand dollars ($51,000), good and lawful money of the United States of America, to the payment of which said sum of money, well and truly to be made and done, the said Principal binds himself, his heirs, executors and administrators, and the said Surety binds itself, its successors and assigns, jointly and severally, firmly by these presents: Signed, sealed and dated this second day of August, A. D. 1900.

Whereas, Said Principal has entered into a certain written contract bearing date on the 23d day of June, 1900, with the People of the State of New York, by Andrew H. Green, George Raines, Charles M. Dow, Thomas P. Kingsford and Alexander J. Porter, composing the Commissioners of the State Reservation at Niagara, for the construction of two three-span each concrete-steel arch bridges with stone facing, twenty-foot gravel roadway and two ten-foot granitoid sidewalks extending across the Niagara River, from the mainland to Green Island and from Green Island to Goat Island, in the Niagara State Reservation, for the sum of one hundred and two thousand and seventy dollars ($102,070), and the right to use the existing bridges, abutments and piers or materials therein.

Now, therefore, the condition of the foregoing obligation is such that if the said Principal shall well, truly and faithfully comply with and perform all of the terms, covenants and conditions of said contract on his part to be kept and performed, according to the tenor of said contract, and shall protect the said State of New York against, and pay any excess of cost as provided in said contract, and all amounts, damages, costs and judgments which may be recovered against the said State or its officers or agents or which the said State of New York may be called upon to pay to any person or corporation by reason of any damages arising or growing out of the doing of said work, *or the repair or maintenance thereof, or the manner of doing the same, or the neglect of the said Principal, or his agents or servants, or the improper performance of the said work by the said Principal, or his agents or servants, and well and truly pay or cause to be paid in full the wages stipulated and agreed

*Albany, N. Y., July 31, 1900—Words "or the repair or maintenance thereof" in 5th line are erased by consent of both parties before the execution of this bond by the Surety Co.—WM. PIERSON JUDSON, Deputy State Engineer of New York.



Stone Stairway, Goat Island. State Reservation at Niagara.
Erected 1900.

to be paid to each and every workman, laborer or employee employed by the said Principal or his agent or agents in the execution of said work described in the said contract, then this obligation shall be null and void, otherwise to remain in full force and virtue.

And the said Surety hereby stipulates and agrees that no change, extension, alteration or addition to the terms of this said contract or specifications accompanying the same, shall in anywise affect their obligation on this bond.

In testimony whereof, the said Principal has hereunto set his hand and seal, and the said Surety has caused this instrument to be signed by its second vice-president and its assistant secretary, and its corporate seal to be hereunto affixed the day and year first above written.

WILLIAM H. KEEPERS, [L. S.]
JAS. H. WYNKOOP, [L. S.]
JOHN M. BRALY, [L. S.]
Principals.

Signed, sealed and delivered
in presence of
WM. PIERSON JUDSON.

THE UNITED STATES FIDELITY
AND GUARANTY CO.,
Surety.

(Corporate seal of Surety Co.) By EDWD. J. SIMMSON,
President.
RICD. D. LAW.

STATE OF NEW YORK, }
County of New York, } *ss.:*

On this 23d day of June, 1900, before me personally came William H. Keepers, James H. Wynkoop and John M. Braly, to me known to be the persons described in and who executed the foregoing instrument, and they severally acknowledged that they executed the same.

[Notary Seal.] HENRY S. GREENBERGH,
Notary Public, New York County, No. 75.

(Acknowledgment By Surety Company.)

(Statement sheet and oath of officers of Surety Company attached to original on file with Comptroller, attached to contract.)

SPECIFICATIONS

FOR

Concrete Steel Bridge at Niagara Falls, N. Y.

1. *Plans.*—The work shall be constructed complete in accordance with the general plans, sections and diagrams herewith submitted, and these specifications.

The specifications and drawings are intended to describe and provide for the complete work. They are intended to be cooperative, and what is called for by either is as binding as if called for by both.

The work herein described is to be completed in every detail, notwithstanding that every item necessarily involved is not particularly mentioned.

The contract price shall be based upon these specifications and drawings, which are hereby signed and made a part of the contract.

2. *Conditions of calculations.*—

	Pounds.
Modulus of elasticity of concrete	1,400,000
Modulus of elasticity of steel	28,000,000
Maximum stress per square inch on steel	10,000
Maximum compression per square inch on concrete	500
Maximum shear per square inch on concrete	100
Maximum tension	50

The above to be exclusive of temperature stresses.

The steel ribs under a stress not exceeding their elastic limit, must be capable of taking the entire bending moment of the arch without aid from the concrete and have a flange area of not less than one one hundred and fiftieth part of the total area of the arch at crown.

3. *Discrepancies.*—In the event of any discrepancies between the drawings and the figures written on them, the figures are to be taken as correct, and in case of any discrepancy between the drawings and specifications, the specifications are to be adhered to.

4. *Foundations.*—All foundations shall be shown on plans, and to conform to the dimensions marked thereon.

In preparing foundations, a temporary cofferdam shall be used and all loose boulders, shale, sand mud or other soft material shall be removed from the rock, and depressions in the rock filled and leveled up with concrete upon which the piers and abutments shall be built; the intention being to obtain a suitable and proper foundation regardless of whether it is found above or below the elevation shown on the plans.

The cofferdams shall be reasonably tight so that they can be pumped out, thus permitting the work to be done under proper conditions.

5. *Cement.*—The cement shall be a true Portland cement, made by calcining a proper mixture of calcareous and clayey earths; and if required, the contractor shall furnish a certified statement of the chemical composition of the cement, and the raw materials from which it is manufactured.

The fineness of the cement shall be such that at least 99 per cent. will pass through a sieve of 50 meshes per lineal inch, at least 95 per cent. will pass through a sieve of 100 meshes per lineal inch, and at least 70 per cent. will pass through a sieve of 200 meshes per lineal inch.

Samples for testing may be taken from each and every barrel delivered, unless otherwise specified. Tensile tests will be made on specimens prepared and maintained until tested at a temperature of not less than 60 degrees Fahrenheit. Each specimen will have an area

of one square inch at the breaking section, and after being allowed to harden in moist air for 24 hours will be immersed and maintained under water until tested.

The sand used in preparing the test specimens shall be clean, sharp, crushed quartz, retained on a sieve of 30 meshes per lineal inch, and passing through a sieve of 20 meshes per lineal inch.

No more than 23 to 27 per cent. of water shall be used in preparing the test specimens of neat cement, and in the case of test specimens of one cement and three sand, no more than 11 or 12 per cent. of water by weight shall be used.

Specimens prepared from neat cement shall after seven days develop a tensile strength of not less than 450 pounds per square inch. Specimens prepared from a mixture of one part cement and three parts sand, parts by weight, shall after seven days develop a tensile strength of not less than 160 pounds per square inch, and not less than 220 pounds per square inch after 28 days. Specimens prepared from a mixture of one part cement and three parts sand, parts by weight, and immersed after 24 hours in water maintained at 176 degees Fahrenheit, shall not swell nor crack, and shall after seven days develop a tensile strength of not less than 160 pounds per square inch.

Cement mixed neat with about 27 per cent. of water or only sufficient to form a stiff paste shall after 30 minutes be appreciably indented by the end of a wire one-twelfth inch in diameter loaded to weigh one quarter pound. Cement made into thin pats on glass plates shall not crack, scale nor warp under the following treatment: Three pats shall be made and allowed to harden in moist air at from 60 to 70 degrees Fahrenheit; one of these will be subjected to water vapor at 176 degrees Fahrenheit for three hours, after which it shall be immersed in hot water for 48 hours; another shall be placed in

water at from 60 to 70 degress Fahrenheit, and the third shall be left in moist air.

Cement for mortar shall not be used directly from any original package, but the contents of five packages shall first be mixed dry in order to obtain uniformity. This dry mixed cement shall then be measured by bulk as wanted and the specified proportions of dry sand shall also be measured by bulk.

All cement shall be kept housed and dry until wanted in the work.

10. *Stone facing.*—The stone facing is to cover the entire structure, including the piers and abutments below water, only excepting the intrados of the arches between the ring stones on each face, and that portion of the abutments buried in the banks.

Portland cement concrete.—Concrete shall be composed of crushed stone which shall be of approved kind and quality of rock which must be known, before crushing, to be free from soil or mud or dirt, or of gravel having irregular surface; the sizes of such stone or gravel to be as hereafter specified. With this crushed stone or gravel shall be mixed clean sharp sand as hereafter specified, which shall be washed if necessary to remove loam or silt, and American Portland cement of the quality above specified; the proportions of sand and cement to be as hereafter specified.

Sand.—Sand which is to be used for forming the concrete and mortar shall be of the best quality available and shall be the cleanest and sharpest found in the vicinity of the work.

Samples of sand.—The contractor shall inform the State Engineer as soon as the contract is awarded what sand is proposed to be used. Samples of this sand shall be obtained by the Engineer and will be examined and tested at the cement testing office of the State Engineer, and if found to contain an injurious amount of loam or silt or material that is friable or soluble, the contractor will be

required to wash the sand before it is brought on the work. It will be the duty of the engineer in charge to see that the soil overlaying the sand bank (if the sand is thus obtained) is cleared away so that no soil shall slide or wash into the sand during its use, and special attention will be given during the progress of the work to see that dirty sand shall not be used in making concrete or mortar. If the sand is obtained by pumping from Lake Erie or the Niagara river, care will be taken that the sand is obtained from the locality free from sewerage and silt.

These materials shall be mixed by machine for all portions of the work except for minor parts requiring small quantities.

The machines used shall be of approved kind for which the proportions for each batch shall be exactly measured; consideration shall not be given to any continuous mixer in which the proportions depend upon shovelers, it being required that the proportions of the several materials and of water shall all be accurately measured for each batch.

The stone or gravel, sand and cement in specified proportions shall be mixed dry in the mixer and the due proportion of water shall then be added and the mixing continued until the product is so thoroughly mixed that every face of every particle of stone or of gravel is completely coated with the cement and sand.

Hand mixing.—Mixing by hand may be permitted on minor pieces of the work where the quantity is less than a charge of the mixer. It shall then be done in the following manner:

The stone or gravel shall be sprinkled while in the pile so that there shall be no dry dust, and the measured quantity for each batch shall then be spread on a plank bed in a layer not more than four inches thick; the measured quantity of mortar shall then be made on a separate mortar-bed where the specified proportions of cement

and of dry sand shall be mixed dry by turning with shovels or by screening as being the most effective and easiest way of securing a perfect mixture which shall be of uniform color and without streaks which will be required before adding water to make the mortar, which shall be done gradually to avoid washing the cement from the sand. The quantity of mortar thus made at each batch shall be no greater than shall be used in 45 minutes after beginning to mix it. If this mortar has set at all before using, it shall not be retempered but shall be thrown away.

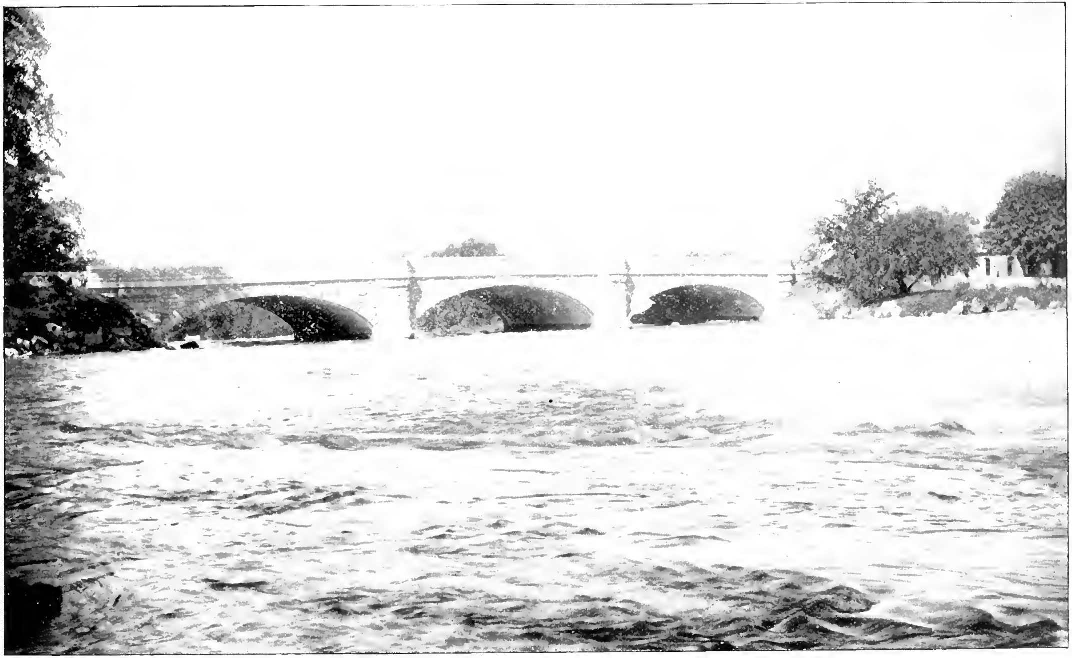
Voids.—Before beginning construction the engineer in charge shall determine the voids in the crushed stone or the gravel which is to form the aggregate of the concrete.

The voids shall be determined by filling a twelve-inch cubical box with well-shaken dry crushed stone or gravel, placing this on accurate scales and weighing the water required to cover the contents.

Proportion.—The proportion of mortar which is to form the matrix of the concrete shall then be varied slightly if necessary in order that it shall exceed the voids by not more than one to two per cent. of the total mass of the aggregate. The proportion shall be used until a change in the character of the aggregate may require a slight variation in the proportion of mortar; the relative propotions of sand and cement being as specified.

Two grades of concrete shall be used in the work for which the proportions shall be as follows, subject to the modification above described, the volume of the material being measured loose:

For the arches between skewbacks, one part Portland cement, two parts sand and four parts broken stone or gravel, which shall pass through a one and one-quarter inch ring, including the total product



Bridge to Goat Island. State Reservation at Niagara. Erected 1901.

of the crusher between one and one-quarter inch and one-quarter inch.

For the foundation abutments, piers and spandrells, one part Portland cement, three parts sand and six parts broken stone or gravel, which shall pass through a two-inch ring, including the total product of the crusher between two inches and one-quarter inch. In the last named portion of the structure, large stones containing not less than one and one-half cubic feet each may be placed in the body of the piers and abutments, provided that each stone is carefully set in mortar on its broadest bed, and so placed that no stone is nearer than eight inches to another stone or to the face of the work, and so that the concrete shall be properly rammed into intervening spaces. Each of these stones shall be washed perfectly clean.

Depositing.—In joining new concrete to other concrete that has already set, precaution shall be taken to secure a perfect bonding by sweeping and washing the work already in place, and by spreading over its surface a thin layer of mortar before the new concrete is placed.

Separate batches.—In any given layer the separate batches shall follow each other so closely that each one shall be placed and rammed before the preceding one has set so that there shall be no line of separation between them. When a machine mixer is used, the successive layers must also follow each other before the preceding layer has set, so that each day's work shall form a monolith. After the concrete has set it shall not be walked upon in less than 12 hours. *See* "Arches."

Ramming.—The operation of ramming shall be so conducted as to form a compact, dense, impervious, artificial stone whose specific gravity is close to the natural rock which was crushed to form the aggregates. The ramming must be so thorough as to perfectly com-

pact the concrete and to fill the voids so that the mortar comes to the surface and that the concrete shall show a perfectly smooth face when the forms are removed.

7. *Concrete facing.*—If concrete facing is used it shall be composed of one part Portland cement and two and one-half parts of clean sharp sand and shall have a thickness of at least one inch and not more than two inches on the arch soffits, arch faces, abutments, piers, spandrells or other exposed surfaces. Facings and backings must be formed simultaneously in the same horizontal layer. In order to gauge the thickness of the facing correctly, a plate of thin metal with convenient handles shall be set on edge parallel to and two inches from the wall of the form; the facing material shall be deposited in the space between this plate and the form; the concrete of the backing shall then be deposited against the back of this plate, which may then be withdrawn and the whole mass thoroughly rammed so as to bond the facing and the backing and to efface the line of demarkation between them.

No piece of stone from the concrete shall be forced nearer to the exposed surfaces than one inch.

8. *Plastering.*—No plastering will be allowed on the exposed faces on the work, and any concrete which is porous must be removed and replaced at the expense of tl e contractor. The inside spaces of the spandrell walls covered by the filling may be plastered with mortar having the same composition as specified for facing.

9. *Protection of work from changes in temperature.*—All finished and unfinished work until thoroughly set shall be kept moist by sprinkling at short intervals in warm weather.

Concrete must be covered with canvas or otherwise protected from the sun, and in cold weather it must be covered in such a way as to retard freezing. During freezing weather the mortar and the

concrete shall be mixed with brine, carefully made by dissolving salt to give about one per cent. of saturation for each degree of temperature below the freezing point.

The brine shall be made in barrels and shall be stirred from the bottom before using to insure uniformity, as shown by frequent observations of salometer. An excess of salt is injurious and a saturated solution which shows free salt lying in the bottom of the barrel shall never be used.

No concrete shall be made when the mercury falls below 20 degrees above zero Fahrenheit, and when the temperature is below freezing point the sand and water shall be heated to 200 degrees Fahrenheit by use of steam coils and otherwise, and special provision shall be made for covering the work at night to prevent freezing as far as possible.

The ring stones shall extend into the work alternately ten and eighteen inches, and the face stones of spandrells and piers shall bed not less than eight inches. Every fifth stone shall be a header and extend into the work at least eighteen inches.

For stone facing the ring stones, cornices and faces of spandrells, piers and abutments shall be of an approved quality of stone. The stone must be of a compact texture, free from loose seams, flaws, discolorations, or imperfections of any kind, and of such a character as will stand the action of the weather. The spandrell walls will be backed with concrete or rubble masonry, to the thickness required. The stone facings shall in all cases be securely bonded or clamped to the backing. All stone shall be rock faced with the exception of cornices and string courses, which shall be sawed or bushhammered. The ring stones shall be dressed to true radial lines and laid in Portland cement mortar, with one-quarter inch joints. All other stones shall be dressed to true beds and vertical joints. No

joint shall exceed one-half inch in thickness, and shall be laid to break joints at least nine inches with the course below. All joints shall be cleaned, wet and neatly pointed.

The faces of the walls shall be laid in true lines, and to the dimensions given on plans, and the corners shall have a chisel draft one inch wide carried up to the springing lines of the arch or string course. All cornices, moldings, capitals, keystones, brackets, etc., shall be built into the work in the proper positions, and shall be of the form and dimensions shown on plans.

11. *Artificial stone.*—If molded railings, etc., are used, woven wire shall be molded into them in such manner as to strengthen all projectings, and they shall be of the designs shown on plans, and be molded in suitable molds. The mortar for at least one inch thick shall consist of one part Portland cement and two and one-half parts sand, and, when the size of the molding will admit, the interior may be composed of concrete of the same composition as specified for the arches. When pedestals, posts or panels carry lamp posts, a four-inch wrought iron pipe shall be built into the concrete from top to bottom, and at bottom shall be connected with a three-inch pipe extending under the sidewalk and connected with gas pipe or electric wire conduit. The pipes shall have no sharp bends, all changes in direction being made by gentle curves.

12. *Arches.*—The concrete for the arches shall be started simultaneously from both ends of the arch, and be built in longitudinal sections wide enough to inclose at least two steel ribs, and of sufficient width to constitute a day's work. The concrete shall be deposited in layers, each layer being well rammed in place before the previously deposited layer has had time to partially set. The work shall proceed continuously day and night if necessary to complete each longitudinal section. These sections while being built

shall be held in place by substantial timber forms, normal to the centering and parallel to each other, and these forms shall be removed when the section has set sufficiently to admit of it. The sections shall be connected as specified under "depositing," and also by steel clamps or rib connections built into the concrete.

13. *Drainage.*—Provisions for drainage shall be made at each pier as follows: A wrought iron pipe of sufficient diameter shall be built into the concrete, extending from the center of each space over pier to the soffit of the arch near springing line, and project one inch below soffit. The surface of concrete over piers shall be formed so that any water that may seep through fill above will be drained to the pipes. The line of drainage will be covered with a layer of broken stone, and the top of pipes will be provided with screens to prevent clogging.

14. *Steel ribs.*—Steel ribs shall be imbedded in the concrete of the arch. They shall be spaced at equal distances apart, and be of the number shown on plans. Each rib shall consist of two flat bars of the sizes marked on plans. The bars shall be in length of about 30 feet, thoroughly spliced together and extending into the abutments as shown. Through the center of each bar shall be driven a line of rivets eight inches c to c with heads projecting about seven-eighths inch from each face of bar, except through splice plates, where ordinary heads will be used. The bars shall be in pairs with their centers placed two inches within the inner and outer lines of the arch respectively as shown. All steel must be free from paint and oil, and all scale and rust must be removed before imbedding in the concrete.

The tensile strength, limit of elasticity and ductility shall be determined from a standard test piece cut from the finished material and turned or planed parallel. The area of cross-section shall not be

less than one-half square inch; the elongation shall be measured after breaking on an original length of eight inches. Each melt shall be tested for tension and bending.

Test pieces from finished material prepared as above described shall have an ultimate strength of from 60,000 to 68,000 pounds per square inch, an elastic limit of not less than one-half of the ultimate, shall elongate not less than 20 per cent. in eight inches, and show a reduction of area at point of fracture of not less than 40 per cent. It must bend cold 180 degrees around a curve whose diameter is equal to the thickness of the piece tested without crack or flaw on convex side of bend. In tension tests the fracture must be entirely silky.

15. *Rivet steel.*—Test pieces from finished material prepared as above described shall have an ultimate strength of from 54,000 to 62,000 pounds per square inch, an elastic limit of not less than one-half the ultimate strength, shall elongate not less than 20 per cent. in eight inches and show a reduction at point of fracture of not less than 50 per cent. It must bend cold 180 degrees and close down on itself without fracture on convex side of bend. In tension tests the fracture must be entirely silky.

16. *Inspection.*—All raw and finished steel and iron and all workmanship thereon shall at all times and at all stages of the work or manufacture be subject to the inspection and acceptance or rejection of the State Engineer and Surveyor or of his authorized representative, who shall at all times while the work or manufacture is in progress have free access to all parts of the furnaces, mills or shops in which the work, or any part thereof, is in progress. The contractor shall freely furnish all desired facilities for inspecting and testing raw material, ingots and finished material at the furnaces and rolling mills, and shall facilitate examination of workmanship

in the shops and during erection. The contractor shall bear no part of the cost of making such tests and inspection, except the furnishing of required facilities and samples.

As soon as any order for rolled or cast steel or iron is placed by the contractor, a complete copy of the order, together with copies of accompanying diagrams or drawings, shall be furnished by the contractor to the State Engineer and Surveyor or his authorized inspector; such orders shall, in all cases, show the name of the furnaces or mills where the material is to be manufactured, with full description of the kind of material wanted. The contractor shall notify the inspector when the material is ready for inspection, and any delay in making such inspection shall be reported to the State Engineer and Surveyor, who will accept no material which has not been duly passed upon by his authorized representative.

The acceptance at any time of any material or work will not be a bar to its future rejection if subsequently found to be defective.

17. *Workmanship.*—The rivet holes for splice plates of abutting members shall be so accurately spaced that when the members are brought into position the holes shall be truly opposite before the rivets are driven. When members are connected by bolts, the holes must be reamed parallel and the bolts turned to a driving fit. Rivets must completely fill the holes, have full heads concentric with the rivets, and be machine driven when practicable.

18. *Centering.*—The contractor shall build an unyielding false work or centering. The lagging shall be dressed to a uniform size so that when laid it shall present a smooth surface, and this surface shall conform to the lines shown on the drawings. The center shall not be struck until at least 28 days after the completion of the arch, unless permission to remove same earlier is given by the State Engineer and Surveyor. Great care shall be used in lowering the

centers so not to throw undue strains upon the arches. The tendency of the centers to rise at the crown as they are loaded at the haunches must be provided for in the design, or, if not, the centers must be temporarily loaded at the crown, and the load be so regulated as to prevent distortion of the arch as the work progresses.

19. *Casing.*—When concrete facing is used, all piers, abutments and spandrell walls shall be built in timber forms. These forms shall be substantial and unyielding, of the proper dimensions for the work intended, and all parts in contact with exposed faces of concrete shall be finished to a perfectly smooth surface, by plastering or other means, so that no mark or imperfection shall be left on the work.

20. *Waterproofing.*—The waterproofing shall consist of a thin coat of mortar composed of one and one-half parts of sand and one part Portland cement.

After the completion of the arches and spandrells, and before any fill is put in, the top surface of arches, piers and abutments, and the lower six inches of the inner surface of the spandrell walls, shall be covered with a suitable waterproof material so as to effectually exclude water.

21. *Fill.*—The space between spandrell walls shall be filled with sand, earth, cinders, or other suitable material, and be thoroughly compacted by ramming, steam road roller, saturated with water, or other effective means, and finished to the proper grade to receive the curbing and pavements.

The roadway on top of the fill shall be composed of about twelve inches of bank gravel to generally conform with the roadways on the approaches and adjacent drives.

22. *Granitoid sidewalks.*—The spaces over which the sidewalks are to be laid shall be first covered with six inches of cinders well com-

pacted. On this shall be laid four inches of concrete, consisting of one part Portland cement, three parts sand and six parts broken stone or gravel—small size—well rammed. The flag divisions shall then be marked off to the desired size. On the surface of the concrete shall then be laid a wearing surface, one inch thick, composed of two parts Portland cement and three parts broken granite or other acceptable stone, in size from three-eights inch downward. It shall be well rammed and troweled to a perfect even surface and rolled with a toothed roller. This wearing surface must be spread on the concrete while the latter is still soft and adhesive, and neat connections must be made with cornices and curbs.

23. *Roadway.* (See paragraph No. 21.)

24. *Balustrades and handrailings.*—The balustrades shall be of the material and of the form and dimensions shown on plans, and shall be brought to true alignment and be firmly fastened to the outside of each sidewalk in the position shown. If an iron handrailing is used, it shall receive two coats of approved paint after erection. The contractor shall submit drawings of stone rail with openings and shall exhibit sample railings during the progress of the work if required.

25. *Erection.*—The contractor shall employ suitable labor for every kind of work, and all stone work shall be laid by competent masons. The contractor will furnish all staging, piling, cribbing, centering, casing and material of every description required in the erection of the work; also all plant, including dredges, engines, pumps, derricks, barges, mixing machines, pile drivers, conveyors or other appliances necessary for carrying on all parts of the work. The contractor shall assume all risks for loss or damage incurred by ice, floods, fire or other causes during the construction of the

work, and shall sufficiently watch and light the work at night during construction.

26. *Cleaning up.*—Upon completion of work, and before final acceptance thereof, the contractor shall remove all temporary work from the river and all rubbish from the streets as provided in paragraph 28.

27. *Maintaining public travel.*—During the progress of the work the contractor shall build and maintain a temporary foot bridge at least six feet wide. It shall be made strong and safe for the use of pedestrians at all hours.

28. *Removal of old bridge.*—The site of the proposed structure is occupied by an old bridge, which with its piers shall be removed by the contractor in a manner satisfactory to the commission. During the preparation for the work and during its progress and after its completion the contractor shall store and dispose of all materials, both new and old, in a manner satisfactory to the Superintendent of the Reservation.

29. *Work embraced by contract.*—The work embraced by contract will be for the structure complete from out to out of abutments or retaining walls, as per plans and specifications, and will embrace fill, pavement, sidewalks and balustrades complete for this length, unless otherwise mentioned.

The approaches to each of the bridges shall be earth fill with top dressing of about twelve inches of bank gravel. They shall connect with the bridges at the elevations shown on the drawings, and each approach shall slope away in such manner as will be in best harmony with the contour of the land adjoining, and of such easy grades as the engineer may approve.

Wing walls shall be built of the forms shown on the plans, and connecting with abutments. They shall be founded at depths well

below frost lines and the sidewalk railing shall be extended over them, as shown on plans.

30. *Approaches.*—The approaches will commence where the work above mentioned ends, and if all or any part of them is included in contract, the same shall be specially mentioned, as provided in paragraph No. 29.

31. *Inspection.*—All materials furnished by the contractor and all workmanship shall be subject to the inspection and acceptance or rejection of the State Engineer and Surveyor.

32. *Name plates.*—Two neat tablets of bronze shall be let into the sidewalk face of the panels of the railing, one inscribed with the names of the officers of the Reservation and the other with the names of the contractors and the year of completion.

33. *Interpretation of plans and specifications.*—The decision of the State Engineer and Surveyor shall control as to the interpretation of the plans and specifications during the execution of the work thereunder.

34. *Expansion joints.*—Expansion joints shall be made in the spandrell walls of each arch above springing lines, or at such other points as may be noted or shown on drawings.

35. *Spandrells.*—The spandrell walls shall have a thickness of not less than 18 inches at any point, and a thickness at bottom of not less than four-tenths of the height of the wall, measured from the top of cornice.

36. *Estimates.*—Approximate estimates of work done shall be made on or about the last day of every month, and a valuation of the same in proportion to contract prices for the completed work will be made by the State Engineer and Surveyor, which sum shall be paid to the contractor in cash on or before the 15th day of the

following month, less a deduction of 15 per cent. upon said valuation, which shall be retained until the final completion of the work.

37. *Final payment.*—Upon the final completion of the work and its acceptance by the Commissioners and the State Engineer and the execution of a guaranty for five years to be of a form approved by the Commissioners, the contractor shall be promptly paid any balance of the contract price which shall then remain due and unpaid.

38. *Imported stone.*—In case it is found that rock which is more satisfactory to the State Engineer and to the contractor can be obtained in Canada, it is understood that the rough stone can be imported uncut, and that this bid is made with the understanding that such importation shall be free from duty.

THIS AGREEMENT, dated this nineteenth day of March in the year one thousand nine hundred and one, made between the firm of W. H. Keepers & Company, parties of the first part, and the people of the State of New York, by the Commissioners ot the State Reservation at Niagara, parties of the second part, and supplemental to an agreement between the same parties dated June 23, 1900.

SUPPLEMENTARY AGREEMENT.

WITNESSETH, That in consideration of and pursuant to a provision contained in said agreement of June 23, 1900, providing for the making of an agreement supplementary to that agreement, the said parties do hereby agree as follows: This agreement and the agreement aforesaid of June 23, 1900, shall be read together, as an agreement between the said parties for the construction of two (2) bridges in said agreements mentioned and referred to, it being the intention of the said parties that this supplemental agreement shall affect and change said agreement of June 23, 1900, only so far as the changes therein and thereto are expressly herein provided for.

It is further mutually agreed that the plans which were approved by the State Engineer and Surveyor on December 3, 1900, shall be considered a part of the contract dated June 23, 1900, and of this contract, and that all unfinished parts and portions of the work covered by said plans approved December 3, 1900, shall be completed in accordance with said plans taken together with said agreements and the specifications forming a part thereof. It is further agreed that the plans approved December 3, 1900, provide for the following changes from the plans originally submitted:

(a) In the bridge between the mainland and Green Island the number of spans shall consist of one (1) center span of one hundred and ten (110) feet and two (2) side spans each one hundred and three (103) feet and six (6) inches.

(b) The piers of the bridges between the mainland and Green Island shall be thirteen (13) feet six (6) inches thick, instead of twelve (12) feet six (6) inches thick.

The piers of the bridges between Green Island and Goat Island shall be eight (8) feet thick, instead of six (6) feet eight (8) inches thick.

(c) The ice breakers of the downstream side of the piers of both bridges shall be omitted; and the facing of the upstream side of the breakers shall be of granite instead of limestone from the level of the foot course to the springing of the arch.

(d) The steel ribs shall be made three (3) inches in from the intrados and extrados of the arch, instead of two (2) inches as called for by the original plans.

(e) Each pair of steel ribs shall be connected together by three-quarter ($\frac{3}{4}$) inch bolts at intervals of about two (2) feet.

(f) The contractors are to furnish and put in place a sufficient additional amount of concrete which will be required to decrease

the allowable compression of the concrete to four hundred (400) pounds per square inch rather than five hundred (500) pounds per square inch, as provided for in the original contract. The amount and disposition of such additional concrete to accomplish this desired result to be in accordance with the plans aforesaid approved December 3, A. D. 1900.

It is further agreed by and between the said parties that the parties of the first part shall have and receive as full compensation for any and all claims on their part arising out of said changes, or any of them, the sum of five hundred dollars ($500) for and on account of extra thickness of piers of said bridges caused by said changes, and the sum of seven dollars ($7) per cubic yard for each and every yard additional concrete in such bridges caused by said changes; and that said contractor shall receive the sum of three hundred dollars ($300) in full compensation for extra richness of concrete due to direction of the State Engineer and Surveyor; and that said contractor shall receive additional compensation for all the bolts required by subdivision D hereinbefore contained at the rate of three (3) cents per pound for said bolts placed in the work completed.

It is further agreed between the parties hereto that the contractor shall during the progress of the work upon said bridges build and maintain a temporary foot bridge ten (10) feet in width which shall be strong and thoroughly safe for the use of pedestrians at all hours, which bridge shall be divided as to its floor space into two (2) equal parts by a strong, substantial hand railing extending lengthwise through the bridge, and that said contractor shall receive the sum of five hundred dollars ($500) in full compensation for building and maintaining said foot bridge, ten (10) feet in width, instead of six (6)

feet in width, which last named width was specified in the original specifications.

And the parties of the second part hereby agree that the parties of the first part shall be paid and receive the aforesaid items of additional compensation in addition to the original contract price of $102,070, and that no deduction shall be made from said original contract price of $102,070 for or by reason of any of the changes hereinbefore specified.

It is further agreed by and between the parties hereto that the parties of the first part shall not later than July 1, 1901, so far complete the work of constructing the bridge between the mainland and Green Island, under and in accordance with the provision of said agreement of June 23, 1900, and of this agreement and of the original specifications, and in accordance with the plans approved December 3, 1900, that said bridge shall then be in such condition that teams and pedestrians shall be able to pass over it with comfort and safety not later than that day, and in case the parties of the first part shall fail to so far complete the construction of the work of said bridge between the mainland and Green Island by July 1, 1901, that teams and pedestrians are unable to pass over it with comfort and safety, then and in such case the parties of the first part shall become liable to the State of New York for and they do hereby promise and agree to pay as liquidated damages for such delay in the completion of such construction work the sum of seventy-five dollars ($75) for each day after the said 1st day of July, 1901, that said bridge shall be in such condition that teams and pedestrians are unable to pass over it with comfort and safety, it being further mutually agreed and understood between the parties hereto that as the liquidated damage clause next above hereinbefore contained is based on the supposition that the contractor will be

able to resume operations in the Niagara River on or before April 1, 1901, and that in case the condition of the Niagara River as to volume of water or running ice shall be such as to prevent the contractor at that time from commencing and continuing operations connected with the springing of the arches in the said bridge between the mainland and Green Island, that all of the time after April 1, 1901, during which they shall be prevented from such causes from commencing and continuing said operations, shall be considered as a credit to the contractor and deduction shall be made therefor in determining the time at which the liquidated damage clause should begin to be enforced.

It being understood and agreed by and between the parties hereto that the liquidated damage as above described and provided for shall not apply in case of delays which will be due to acts of God or to the elements or unpreventable accidents beyond the power of the contractor to overcome.

It being left to the discretion of the State Engineer and Surveyor and said Commissioners to determine whether any delays to which the hereinbefore liquidated damage clause would apply have been caused by the condition of the Niagara River, running ice therein, acts of God, the elements, or unpreventable accidents beyond the power of the contractor to overcome.

It is hereby mutually understood and agreed by and between the parties hereto that the foregoing supplemental agreement extends and relates to all matters of difference now or heretofore existing between the contractor and the Commissioners, and this supplemental agreement is entered into for the purpose of adjusting and determining all such differences which have existed or now exist, and it is hereby agreed between the parties hereto that the same are now fully and finally adjusted by this supplemental agreement.

In witness whereof the parties to this agreement have hereunto set their hands this 19th day of March, A. D. 1901.

W. H. KEEPERS & CO.,

Contractor.

By W. H. KEEPERS.

ANDREW H. GREEN,

THOMAS P. KINGSFORD,

GEORGE RAINES,

ALEX. J. PORTER,

CHAS. M. DOW,

Commissioners of the State Reservation at Niagara.

Approved March 19, 1901.

EDWARD A. BOND,

State Engineer and Surveyor.

AGREEMENT

FOR

ADDITIONAL TRACKS IN THE RIVERWAY, STATE RESERVATION AT NIAGARA.

THIS AGREEMENT, Made the 2d day of July, 1901, between The Niagara Falls and Suspension Bridge Railway Company, party of the first part, and the Commissioners of the State Reservation at Niagara, party of the second part, Witnesseth:

Whereas, under and pursuant to an agreement made by and between the parties hereto, dated the 23d day of September, 1899, the party of the first part has constructed for the party of the second part, a single street railway track upon and along Riverway upon the State Reservation at Niagara, between Falls and Niagara streets, which track the party of the first part is using under a license therefore issued by the party of the second part, dated the 23d day of September, 1899; and

Whereas, the party of the first part desires the use of a double street railway track along a portion of said Riverway and also of turnouts to its passenger station fronting upon said Riverway, all as laid down upon the map hereto attached.

Now, for the purpose of changing or altering said single street railroad track to a double track with turnouts, as shown upon the said map attached, it is agreed as follows:

1. The party of the first part agrees to construct on and along Riverway upon the State Reservation at Niagara, between Falls and Niagara streets, street railroad tracks with turnouts in complete conformity to the maps, plans and specifications hereto attached and made a part hereof, and to pay all expenses connected therewith

incurred by the Commissioners, and to make all changes and alterations in the said existing track necessary to make the tracks as finally constructed and completed, conform to the map hereto attached.

2. Such work shall be commenced at once and prosecuted diligently to completion.

3. The work of construction shall be carried on under the direct supervision of said Commissioners and subject to such regulations and directions as they may from time to time make and give, and in giving such instructions and directions, the Superintendent of the Reservation shall be treated and obeyed as the agent and representative of the Commissioners.

4. The party of the first part shall keep an exact and itemized statement of all the cost and expense of such construction, including expenses incurred by the Commissioners in connection therewith for counsel, engineering or otherwise, and shall furnish to the Commissioners a detailed written statement thereof, and when the work is completed the Commissioners shall determine and certify the reasonable cost of such work, having power to determine what are proper expenses, payments and charges.

5. The said tracks and all work, material and constructions connected therewith within the limits of the State Reservation, shall at all times be and remain the property of the State, free from all lien, claim or charges of the party of the first part, which shall have no claim or charge whatever against the Commissioners or either of them, or the State, for the work done or payments made hereunder.

6. Upon the completion of said tracks, and when the same are ready for use, the said first party may use the same for street railroad purposes pursuant to and under the terms of a license granted

by the said Commissioners to the party of the first part, dated the 23d day of September, 1899, for the use of street railroad tracks in said Riverway. And it is further agreed that the terms of the paragraph of said license numbered one are hereby changed and amended so that the party of the first part shall not be called upon or required to make the first payment of the license fee of $1,000 per annum in advance for the use of said tracks, and the same shall not be due and payable until the expiration of such time as license fees at said rate computed from the 23d day of September, 1899, shall equal the amount expended or advanced by the party of the first part in the construction of said street railroad tracks in said Riverway under and pursuant to an agreement between the parties hereto made the 23d day of September, 1899, and the further amount expended or advanced by it under and pursuant to this agreement.

7. This agreement is made subject to the provisions of section 108 of the Railroad Law and shall not be of force until the Commissioners of the Land Office have given the consent therein required.

8. The construction of said work and the payment of the expenses connected therewith shall not constitute any claim or ground for claiming that said license shall not be revocable at the pleasure of the Commissioners.

9. The party of the first part, in consideration of said license, agrees to indemnify and save harmless the State of New York, the Commissioners of the State Reservation at Niagara and each of them, and their and each of their successors in office, against all costs, payments, expenses, suits and damages whatsoever, arising from or growing out of the improper condition of said tracks in said Riverway, or the use thereof, by the first party or any of its

allied roads named in the said license during the construction of said tracks and the continuance of said license.

In witness whereof, the parties hereto have executed this agreement in duplicate the day and year first above written.

NIAGARA FALLS AND SUSPENSION BRIDGE RAILWAY COMPANY,

Attest:

R. F. RANKINE,
Secretary.

By W. CARYL ELY, *President*.
GEO. RAINES.
T. P. KINGSFORD.
CHAS. M. DOW.
ALEX. J. PORTER.

[Seal.]

STATE OF NEW YORK, }
County of .... } *ss.:*

On this fourteenth day of August, in the year of our Lord one thousand nine hundred and one, before me personally came W. Caryl Ely of the city of Buffalo, N. Y., to me personally known, who being by me duly sworn, did depose and say that he resides in the city of Buffalo, N. Y., and is the president of the Niagara Falls and Suspension Bridge Railway Company; that he knows the corporate seal of said company; that the seal hereunto affixed is said corporate seal, and that it was hereunto affixed by order of the board of directors of the said company, and he signed his name thereto as president, by like order.

HUGH McDONALD,
Notary Public, Niagara County, N. Y.

Certificate filed in Erie county.

SPECIFICATIONS

FOR

ADDITIONAL TRACKS IN THE RIVERWAY OF THE STATE RESERVATION AT NIAGARA FALLS.

The tracks shall be laid in conformity with the attached plan, and the grade shall conform to the street levels as now occupied. The track now in place shall be moved two (2) feet towards the river; the gutter on the river side of the driveway shall be moved back two feet and carefully relaid, the present location of the gutter to be replaced by macadam. The curb on the east side of driveway, commencing at a point three feet southerly of the first iron pole of overhead construction, shall be set back on curve so that when tangent is reached it will be two feet back of its present position, the whole of the straight line to be moved back two feet and care taken that the curb at Niagara street is properly recut and set. Any curbstone broken must be immediately replaced and no stone shall be less than thirty inches in length. All surface and overhead work must strictly conform to the tracks already in place, and the engineer in charge shall have full authority to cause the removal or correction of work improperly executed. All detail specifications of original work of every character shall apply to these additional tracks. Where tracks cross the sidewalk in front of the car barn, great care must be exercised to close up every opening excepting the space necessary for the flange of the wheel, and no guard-rail or part of frog shall show above the level of the sidewalk. All necessary changes shall be made in catch basins, or otherwise, to take care of drainage, and when work is completed the whole length of the Riverway disturbed shall be properly resurfaced and thoroughly rolled after being well wet down.

At a meeting of the Commissioners of the Land Office, held at the office of the Secretary of State, on Thursday the 27th day of February, 1902, at 9.30 o'clock A. M.

Present: John T. McDonough, Secretary of State; Nathan L. Miller, Comptroller; John P. Jaeckel, Treasurer; John C. Davies, Attorney-General; Edward A. Bond, State Engineer and Surveyor.

The Secretary of State in the chair.

Mr. F. W. Stevens, Attorney for the Commissioners of the State Reservation at Niagara, applied for consent of the Commissioners of the Land Office, pursuant to the provision of section 108 of the Railroad Law, as amended by chapter 710, Laws of 1899, to construct, without expense to the State, additional street railroad tracks upon and along Riverway, between Falls and Niagara streets, in the city of Niagara Falls.

Upon motion of the State Engineer and Surveyor, the following resolution was adopted:

Resolved, That the Commissioners of the Land Office do hereby consent, pursuant to section 108 of the Railroad Law, as amended by chapter 710, Laws of 1899, that the Commissioners of the State Reservation at Niagara may construct, without expense to the State, additional street railroad tracks upon and along that portion of Riverway, so called, between Falls and Niagara streets, in the city of Niagara Falls, as shown upon a map submitted and filed herewith, and that they may issue revocable licenses for the use of said tracks as provided in section 108 of the Railroad Law.

STATE OF NEW YORK,
Office of the Secretary of State, } *ss.:*

I have compared the preceding extract from the minutes of the proceedings of the Commissioners of the Land Office with the proceedings of said Commissioners on file in this office, and I do hereby

certify the same to be a correct transcript therefrom and of the whole thereof relating to the construction of street railroad tracks upon and along a portion of Riverway, so called, in the State Reservation at Niagara.

Witness my hand and the seal of office of the Secretary of [Seal.] State, at the city of Albany, this twenty-eighth day of February, one thousand nine hundred and two.

JOHN T. McDONOUGH,

Secretary of State.

APPENDIX.

BULLETIN

OF THE

New York State Museum.

FREDERICK J. H. MERRILL, Director.

No. 45. April, 1901.

GUIDE TO THE

GEOLOGY AND PALEONTOLOGY OF NIAGARA FALLS AND VICINITY

By AMADEUS W. GRABAU, S. D.,

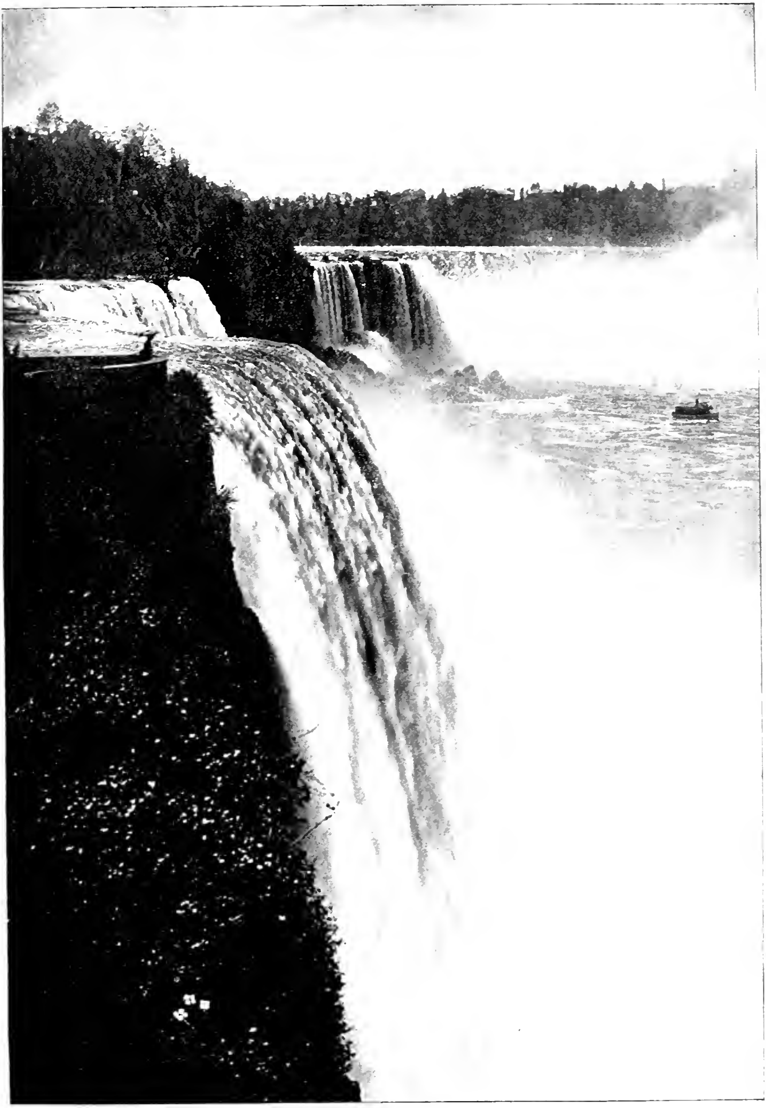
Professor of Geology Rensselaer Polytechnic Institute, and Lecturer in Geology Tufts College.

PREFACE

With the support and cooperation of the Buffalo society of natural sciences and the department of paleontology of the state museum, Dr Grabau has prepared this guide to the geology and paleontology of Niagara falls and vicinity with the special purpose of affording to visitors to Buffalo during the season of the Pan-American exposition in 1901 a viaticum in their tours through this region renowned for its scenic features and classic in its geology. The ground has been the subject of a multitude of scientific treatises concerned now with the succession of events in the upbuilding of the rock strata along the canyon of the river; again with the nature of the organic remains inclosed in these strata; sometimes with the changes which the falls have undergone in historic times, but for the most part with the perplexing problems of the origin of the present drainage over the great escarpment and through the gorge, the raison d'être of the falls, the various changes in the course and work of the Niagara river since its birth and the significance of the present topography of the region. These scientific investigations began with the careful surveys instituted by the late Prof. James Hall, state geologist and paleontologist, during the years of his explorations in the 4th geologic district of this state from 1837-43, who, in addition to his record of the work done by this tremendous agent, derived from this region an important term in the New York series of rock formations, the Niagara group, and portrayed the organisms of the various strata which are so superbly exposed along its great channel. Lyell and Bigsby, Logan, Gilbert, Upham, Spencer, Leverett and Taylor are among the names of others who have contributed, from various points of view, facts and hypotheses relating to the geologic history of the river. In no one place however has the general purport of all these various studies been brought together so that the intelligent traveler or student can acquire them in convenient form. It is for this reason that Dr Grabau's work in bringing together in concise form the essence of these investigations, tempered and proved by his own review of them in the field, will not fail to prove serviceable to a large element of the public.

John M. Clarke
State paleontologist

Plate 1



Niagara Falls from Father Hennepin's view point.

INTRODUCTION — NIAGARA FALLS

AND

HOW TO SEE THEM[1]

The falls of Niagara have been known to the world for more than 200 years. Who the first white man was that saw the great cataracts is not known, but the first to leave a description was the French missionary, Father Louis Hennepin, who, in company with La Salle, visited the falls in 1678. He was the first white man to use the name, Niagara, for the river and the falls, a name which had been applied by the Neuter Indians, who occupied the territory on both sides of the river prior to the year 1651, when they were conquered by the Senecas, who after that occupied and possessed the territory.[2] In the native language the name is said to signify "the thunder of the waters".

The first sight of the great cataracts must have made a powerful impression on Father Hennepin, unprepared as he was by previous descriptions save those given him by his Indian allies and guides. He speaks of the falls as "a vast and prodigious Cadence of Water which falls down after a surprizing and astonishing manner, insomuch that the Universe does not afford its Parallel".[3] He considered the falls "above Six hundred foot high", and adds that "the Waters which fall from this horrible Precipice, do foam and boyl after the most hideous manner imaginable, making an outrageous Noise, more terrible than that of Thunder, for when the

---

[1] Niagara falls are reached from Buffalo by train or electric cars, both of which run at frequent intervals. A direct line of railway runs from Rochester to the falls by way of Lockport. Direct railway connection with western cities is obtained by way of Suspension bridge, while from Toronto and other cities north of Lake Ontario the falls may be reached by train direct, or by boat to Lewiston or Queenston, and thence by train or electric road to Niagara. All electric cars on the New York side run to or past Prospect park, and most of them pass the railway stations. The railway stations are within walking distance of the falls.

[2] Porter, Peter A. Goat island. 16th an. rep't comr's state reservation, 1900.

[3] A new discovery of a vast country in America. 1698. p. 29. Reprinted in part in special report N. Y. state survey for 1879.

Wind blows out of the South, their dismal roaring may be heard more than Fifteen Leagues off."[1]

If today, from our vantage ground of precise knowledge, we smile on the extravagant estimates of Father Hennepin, it may be asked, who among us, that is capable of admiration and enthusiasm at the sight of nature's grand spectacles, would, on coming unprepared on these great cataracts, be able to form a calm and just estimate of hight and breadth and volume of sound?

Since the time of La Salle and Hennepin, the falls have been viewed by a constantly increasing number of visitors. For Americans of the present generation and for people of other lands as well, Niagara has become a sort of Mecca, to which they hope once in their life time to journey. With many this is a hope long deferred in realization, with most perhaps it is a dream never realized, but those who do go and see, come away with their conceptions of nature much enlarged and with memories which cling to the end of life. Fully to appreciate Niagara, one must give it more than a passing glance from the carriage of an impatient driver, who is anxious to have you " do " Niagara in as short time as possible, that he may secure another " fare ". Learn to linger at Niagara, and give nature time to impress you with her beauty and her majesty. " Time and close acquaintanceship," says Tyndall, " the gradual interweaving of mind and nature, must powerfully influence any final estimate of the scene ". And the growing impression which this incomparable scene produced on him, served to strengthen the desire " to see and know Niagara falls as far as it is possible for them to be seen and known".[2]

It is surprising that many of the visitors to the falls allow themselves to be hurried past some of its most beautiful spots and to bestow on others only casual attention, and then waste a wholly disproportionate amount of time in the museums and curio stores looking for souvenirs purporting to come from Niagara but generally manufactured elsewhere. Real and valuable Niagara souvenirs may be had for the trouble of picking them up, in the minerals, fossils and shells which abound in the vicinity of the falls.

[1] *Loc. cit.*

[2] Tyndall. Fragments of science, " Niagara ".

And, while one gathers these, one's knowledge of Niagara becomes broadened, and the perception grows that there are other lessons to be learned in this region, lessons of even more tremendous import than those taught by the cataracts.

The pedestrian has by far the best opportunity to see and enjoy nature as she is only to be seen and enjoyed at Niagara. The stately forest beauty of Goat island, unequaled in the estimation of those competent to judge, by that of any other wooded spot of similar size; the constantly changing views of gorge and falls and rapids which are obtained from nearly every path on the islands and the mainland on both sides of the river; the magnificence of the turbulent waters as they rush toward you, wave piling on wave, till it seems as if the frail-looking structure on which you stand must inevitably be carried away by them—none can enjoy these to their full extent while sitting in a carriage, though it move never so slowly, or while being compelled to listen to the descriptions and explanations of an unsympathetic and unappreciative driver. If you must ride, patronize the reservation carriages, which leave you wherever you wish to stop and take you on again at your own pleasure.[1]

Views from the New York side

The first view of the falls which the visitor on the New York side enjoys is generally from Prospect point, or some of the more elevated view points along the brink of the gorge in Prospect park (*see* frontispiece, pl. 1). While impressive, this view by no means reveals to its full extent the matchless grandeur of the cataracts, and in this respect the visitor on the Canadian side has the advantage. However, the views from Prospect point and Father Hennepin's view point should be obtained by every one, and it may be that some will find greater attraction in these than in the more comprehensive views obtained from the other side. While in Prospect park, it is well to descend to the foot of the inclined railway, and get the views

[1]These carriages are run at intervals of 15 minutes, starting from Prospect park, and making the circuit of Goat island. The fare is 15c for the round trip, and stop-overs at all places, and for any length of time on the same day, are allowed.

of the falls from below. The ride on the *Maid of the Mist* will be found an interesting and novel experience, besides affording views of the cataracts obtainable in no other way; but most people will defer this till they have seen more of the cataracts and rapids from above. In visiting the foot of the falls, an umbrella should be taken, while a waterproof cloak will be found of great advantage, for the visitor is apt to be drenched by the spray which will be blown on him unawares. Caution is necessary here, as everywhere at Niagara, to avoid accidents. In the talus heaps of limestone fragments, minerals and occasionally fossils may be found.

From Prospect point the visitor should next turn his attention to Goat island, "the most interesting spot in all America", as Capt. Basil Hall called it. The unpoetic name of this island is, as Mr Porter tells us[1], commemorative of the power of endurance of a male goat, which, in company with a number of other animals, had been left on this island uncared for during the severe winter of 1770-71, and proved the only survivor.

From the bridges which cross to Green, and thence to Goat island, memorable views of the rapids above the falls may be obtained; and the visitor will do well to pause, that he may become impressed by the magnificence of the spectacle. Perhaps he will feel as did Margaret Fuller, who said: "This was the climax of the effect which the falls produced upon me—neither the American nor British fall moved me as did these rapids." The naturalist will be interested to note that, in spite of the fearful rush of water, fresh-water mussels have found a lodging place among the more protected rocks, where they seem to thrive well. Along the shores of the islands, in places where other animals would find it hard to gain a foothold, numerous small gastropods may be found clinging to the slippery rock surfaces.

On Goat island, despite the so-called "improvements" for the convenience of visitors, nature still reigns supreme. The virgin character of the forest is almost undisturbed, as it was when the red man regarded this as the sacred abode of the Great Spirit of

---

[1]Porter. Goat island.

Plate 2

Luna Falls, and the limestone fragments at its base (Copyright by Underwood & Underwood, New York)

Niagara. The botanist will here find a greater variety of plants within a given space than in almost any other district.[1]

But it is in the wonderful views of the falls and the rapids and the gorge which can be obtained from this island, that its chief attraction lies. The various view points are easily found, and the stroller about Goat island would best come on them unawares. Mention may be made of the glimpses of the American falls obtained from the head of the stairway leading to Luna island, as well as from the island itself, and the panorama of rapids, falls and gorge from the Terrapin rocks at the edge of the Horseshoe falls. Every visitor is advised to descend the Biddle stairway and view the falls from below. No charge is made unless one wishes to enter the Cave of the winds, a most thrilling experience for a person of nerve and one unparalleled by any other which may legitimately be obtained at Niagara. But, even if one does not care to go behind the falls, a visit to the foot of the stairway, and a walk along the path at the base of the vertical cliff of limestone will well repay the exertion of the climb. Many noble views of the gorge and the falls may be obtained from the stairway, while from certain points below, impressive sights of the small central fall are to be had. Here too can be seen the undermining action of the spray, which removes the soft shale, leaving the limestone ledges projecting till in the course of time they fall for want of support. On the talus slopes at the foot of the cliff good specimens of minerals and occasional fossils may generally be obtained.

After leaving the Biddle stairway, and the Terrapin rocks, the visitor will proceed southward along the river bank to the bridge leading to the Three Sister islands. On the way the geologist will pause where a wood-road leads off to the left into the famous gravel pit of Goat island, since there the shell-bearing gravels are exposed.[2]

---

[1]A catalogue of the flowering and fern-like plants growing without cultivation in the vicinity of the falls of Niagara, by David F. Day, is published in the 14th annual report of the commissioners of the state reservation. In this a total of 909 species are recorded, a large proportion of which are credited to Goat island.

[2]These shells are described in chapter 5.

A small fall known as "The Hermit's cascade" lies between Goat island and the First Sister. In the pool at the foot of this fall Francis Abbot, the Hermit of Niagara, was wont to take his daily bath.

From the bridges and from the islands unsurpassed views of the upper rapids are obtained. These are particularly impressive when seen from the rocks of the Third Sister. Of these rapids as seen from the Terrapin rocks, the Duke of Argyle wrote:

When we stand at any point near the edge of the falls, and look up the course of the stream, the foaming waters of the rapids constitute the sky line. No indication of land is visible—nothing to express the fact that we are looking at a river. The crests of the breakers, the leaping and the rushing of the waters, are still seen against the clouds as they are seen in the ocean, when the ship from which we look is in the trough of the sea. It is impossible to resist the effect of the imagination. It is as if the fountains of the great deep were being broken up, and that a new deluge were coming on the world. The impression is rather increased than diminished by the perspective of the low wooded banks on either shore, running down to a vanishing point and seeming to be lost in the advancing waters. An apparently shoreless sea tumbling toward one is a very grand and a very awful sight. Forgetting, then, what one knows, and giving oneself to what one only sees, I do not know that there is anything in nature more majestic than the view of the rapids above the falls of the Niagara.

On returning to Goat island the visitor may take the reservation carriage for a return to Prospect park, or he may continue his walks around or across Goat island.

In front of Prospect park the electric cars may be taken to cross the river, the bridge-toll which every foot passenger has to pay, being included in the car fare.

Views from the Canadian side

The Canadian side is reached either by bridge or by the steamer *Maid of the Mist*.[1] Every visitor to the falls should obtain the views from the Canadian side, which are in many respects superior to any obtainable on the New York side. Several rustic arbors have been constructed along the brink of the gorge in Queen Victoria park, and here the visitor may tarry for hours and not weary of

[1] If the visitor plans to take the belt line ride—Niagara, Queenston, Lewiston—he will have opportunity to stop off in Queen Victoria park, and need not make a special crossing.

the sights he beholds. The remarkable vivid green of the water of the Horseshoe falls will excite the observer's interest, and question. Tyndall observes that, while the water of the falls as a whole "bends solidly over and falls in a continuous layer. . . close to the ledge over which the water rolls, foam is generated, the light falling upon which, and flashing back from it, is sifted in its passage to and fro, and changed from white to emerald-green."[1]

Near the edge of the Horseshoe falls are the remains of Table rock, formerly a projecting limestone shelf of considerable extent, and a favorite view point. Huge portions of this rock have fallen into the gorge at various times, the most extensive falls occurring in 1818 and 1850, with minor ones between and since. On one occasion some forty or fifty persons had barely left the rock before it fell. From the remaining portion of this rocky platform a good near view of the Horseshoe falls is obtained, though the visitor is apt to find himself in a drenching shower of spray at almost all times.

Beyond Table rock, in the upper end of the park, and on the Dufferin islands many attractive walks are to be met with. These are generally little visited and afford an opportunity for solitude and escape from the crowds of sightseers. Some of the best views of the rapids above the falls are to be obtained here. A wooded clay cliff bounds the park on the landward side, generally rising steeply to the upland plateau. Here on July 25, 1814, the memorable battle of Lundy's Lane was fought between the British and the Americans; "within sight of the falls, in the glory of the light of a full moon, the opposing armies engaged in hand-to-hand conflict, from sundown to midnight, when both sides, exhausted by their efforts, withdrew from the field".[2]

At the head of the park, a road leads to the upland, where is situated the famous burning spring. The inflammable gas which here bubbles through the water of the spring is chiefly sulfureted hydrogen, but the quantity is such as to produce a flame of considerable magnitude, and it is asserted that the supply has not diminished for the hundred years or more that the spring has been known to exist.[3]

---

[1] *Loc. cit.*

[2] Porter.

[3] An admission fee is charged here.

The gorge below the falls

The gorge of the Niagara river should be seen from both sides. Here as elsewhere the pedestrian with abundant time has the best opportunity to see the numerous interesting and attractive features; but, since distances here are considerable, it is perhaps more advisable to avail one's self of the conveyances afforded.[1]

The best view of the gorge is afforded by going down the river on the Canadian side and returning by the gorge road. In this way the passenger on the cars gets nearest to the river, particularly if the right hand seats are selected. If the visitor however prefers to go down the river on the gorge road, and return by the Canadian line, let him choose the left side of the cars as nearest to the river in both cases.

After passing Clifton on the Canadian side, and the last of the bridges which here span the gorge, the observer begins to have a view of the whirlpool rapids, which even from this elevation have a threatening aspect. It was through these rapids and through the whirlpool below, that the first *Maid of the Mist* was safely navigated in 1861, having at the time three men on board—a feat which has never been repeated. Through this same stretch of rapids Capt. Webb made his fatal swim, paying for the foolhardy attempt with his life. After passing the rapids we reach the whirlpool, of which good views are afforded from many places along the top of the bank. After crossing several small ravines, that of Bowmans creek is reached. This ravine is a partial reexcavation of the old drift that filled St Davids channel.[2] From the upper end of the bridge which crosses the ravine, a path leads down to the water's edge, the ravine being one of singular attractiveness to the lover of wild woodland scenery. A short distance beyond the bridge is the Whirlpool station of the electric road. Here, from a little shelter built on the extreme point, fine views of the whirlpool and the river above and below it are obtained. The river here makes a right-angled bend, the whirlpool forming the swollen elbow. In the rocky point projecting from the

---

[1] The visitor will do well to purchase a belt line ticket, which entitles him to make the circuit in either direction and to stop at all important points. The Canadian scenic route will take him along the top of the bank, while the gorge road, on the New York side, takes him close to the edge of the water.

[2] *See* map, and chapter 1.

bank on the New York side the succession of strata is finely shown[1]; and from this point northward the New York bank exposes a nearly continuous section as far as the mouth of the gorge at Lewiston.

A short distance below the whirlpool we reach Foster's flats, or Niagara glen, as it is more appropriately called. This is visited by comparatively few tourists, though it is one of the most attractive spots along the gorge.[2] It marks the site of a former fall, and, besides its interest on that account deserves to be visited for its silvan beauty and its wild and picturesque scenery of frowning cliff, huge moss-covered boulders and dark cool dells, where rare flowers and ferns are among the attractions which delight the naturalist. Many good views of the river and the opposite banks may here be obtained, and the student of geology will find no end to instructive features eloquent of the time when the falling waters were dashed into spray on the boulders among which he now wanders. After leaving Niagara glen the visitor should stop at Queenston hights and obtain the view which is here afforded.[3] If possible the more comprehensive views from the summit of Brock's monument should be obtained.[4]

After descending and crossing to the New York side, one may return directly by the gorge road, leaving the inspection of the fossiliferous strata for another day, or one may, after a rest at the hotel, or on the river bank, spend some hours in studying the sections exposed along the New York Central railroad cut.[5]

The return journey by the gorge road is one of great interest, as it carries the visitor close to the rushing waters of the river. Walking along the roadbed is forbidden, and stops are made only at the regular stations.[6] The first of these is the Devil's hole, a cavern in the rock, of the type described in chapter 3 and supposed to have figured in Indian lore. The ravine of Bloody run, a small stream generally dry during the summer season, was the scene of a fearful massacre of the English soldiers by the Seneca Indians in 1763, the

[1] For a description of these, *see* chapter 3.

[2] *See* chapter 2.

[3] *See* chapter 1.

[4] An admission fee is charged here.

[5] Waggoner's hotel near the Lewiston suspension bridge makes a convenient stopping place, specially if one desires to visit the fossiliferous sections. The Cornell, at the ferry landing, opposite the Lewiston railroad station, is also recommended.

[6] In stopping off, be sure to obtain stop-over checks from the conductor.

whole party with the exception of two, with wagons and horses, being driven over the cliff by the savages, and dashed to pieces on the rocks below. Next above the Devil's hole is Ongiara[1] park, a picturesque wooded slope opposite the southern end of Foster's flats, and like parts of that region are dotted with enormous blocks of limestone, which have fallen from the bank above. A short distance above this we come to the whirlpool, where a stop of some time can profitably be made. But by far the most attractive place at which to stop is the whirlpool rapids. The water which here rushes through a narrow and comparatively shallow channel, makes a descent of nearly 50 feet in the space of less than a mile, and its turbulence and magnificence are indescribable. Seen at night by moonlight, or when illuminated by the light from a strong reflector, the spectacle is beyond portrayal. We may perhaps not inaptly apply Schiller's description of the Charybdis to these waters:

> Und es wallet und siedet und brauset und zischt,
> Wie wenn Wasser mit Feur sich mengt.
> Bis zum Himmel spritzet der dampfende Gischt,
> Und Well' auf Well' sich ohn' Ende drängt,
> Und wie mit des fernen Donner's Getose,
> Entstürzt es brüllend dem finstern Schosse.

Fossiliferous sections

These sections are to be seen on the cut of the New York Central and Hudson river railroad, Lewiston branch, and along cuts of the Rome, Watertown and Ogdensburg railroad at Lewiston hights. The former are approachable from Lewiston on the north or the Devil's hole station on the south. The approach from Lewiston is the more natural, as it will give the strata in ascending order. Waggoner's hotel makes a convenient starting point. Follow the car tracks southward to where a road leads off on the left. Entering this, a wood-road is found to lead off on the right, which when followed will bring you on the terrace formed by the quartzose sandstone bed, and on which the bridge towers stand. A quarry in the white sandstone by the roadside gives an opportunity to study this rock, which is practically barren of fossils. Beyond this the tracks of the New York Central railroad are reached, which, after traversing a short tunnel hewn out of the Medina sandstone, bring you to the sections in the gorge (plate 12). Care must be exercised in exploring

[1] One of the 40 ways of spelling Niagara.

these sections, as trains are frequent, and rockfalls from the cliffs are among the daily occurrences. With a little caution however the sections may be studied without danger. The total amount of walking necessary from Waggoner's hotel to the Devil's hole is about 3 miles. Near the upper end of the section, where the track enters a rock cutting, a steep path along the river bank leads to the top of the rocky plateau, and a short walk along the top of the bank will bring you to the Devil's hole station. One may also climb the bank in the quarry at the head of the section, and, passing along the top, reach the Devil's hole station by crossing the bridge over the rock-cut before mentioned. At the Devil's hole station[1] one may either take the surface car, which runs to Niagara falls at frequent intervals (5c fare), or, by paying the admission to the Devil's hole, descend to the gorge road and continue the journey to the falls. (A ticket or 50c fare is required here.)

If the sections are approached from the upper end, the Devil's hole station may be reached by the surface electrics[2] or the visitor may leave the cars of the gorge road at the lower Devil's hole station, and, paying the admission fee, ascend the banks by the stairs and paths. The path from the Devil's hole station to the sections leads close along the brink of the gorge. If the sections are visited in the forenoon, the investigator will find himself in the shadow of the cliffs, which is most grateful on a warm summer day.

The sections on the Rome, Watertown and Ogdensburg railroad are reached from Waggoner's hotel by paths leading up " the mountain " one of which begins on the New York Central tracks not far north of the tunnel.

Geologic nomenclature

Geologic time is divided into five great divisions, based on the progress of life during the continuance of each. These are:

5 Cenozoic time, or time of " modern life "
4 Mesozoic time, or time of " medieval life "
3 Paleozoic time, or time of " ancient life "
2 Proterozoic time, or time of " first life "
1 Azoic time, or time of " no life "

---

[1]Refreshments may be obtained here.

[2]These electrics run from near Prospect park to the Devil's hole and return, at short intervals.

Each of these time divisions is farther divided into great eras, those of Paleozoic time being given in the annexed table. Each era is in general divisible into three periods of time, the early, middle, and later, for which the prefixes *paleo* (or *eo*), *meso* and *neo* are used. The farther division of the periods is into epochs.

During the continuance of each great time division of the geologic history of the earth, more or less extensive rock systems were deposited, wherever the conditions were favorable. Thus the Paleozoic rock system is that deposited during Paleozoic time. That part of the Paleozoic rock system which was deposited during the Siluric era, is called the Siluric rock series, and similarly, the name of each of the other great *eras* is also applied to the rock series deposited during its continuance. In like manner each geologic *period* has its corresponding *group* of rocks deposited during its continuance. These rock groups and their farther subdivision into stages have, in New York, received local names, the name of the locality where the rocks are best developed being selected. The rocks formed during Proterozoic and Azoic time are generally spoken of as pre-Cambric.

The following table embodies the result of the latest studies.[1] The thicknesses are chiefly obtained from well records published by Prof. I. P. Bishop. The relations of these strata to each other in this region are shown in the north and south section from Canada to the New York-Pennsylvania line, presented in fig. 1.

Ever since the days of Lyell and Hall the life history of Niagara and the origin of the Great lakes has engaged the attention of geologists the world over. Among the names prominent in connection with studies of the geology of Niagara in one or more of its aspects, may be mentioned those of Bishop, Clarke, Claypole, Davis, Fairchild, Gilbert, Hall, Hitchcock, Lesley, Lyell, Newberry, Pohlman, Ringueberg, Shaler, Spencer, Tarr, Taylor, Upham and Wright, besides a host of others.[2]

---

[1] Clarke and Schuchert. Science. n. s. Dec. 15, 1899, 10:3. It will be found to differ in some respects from the table published in the author's Geology of Eighteen Mile creek, etc.

[2] In the field work I have had the efficient assistance of my friend Mr R. F. Morgan of Buffalo.

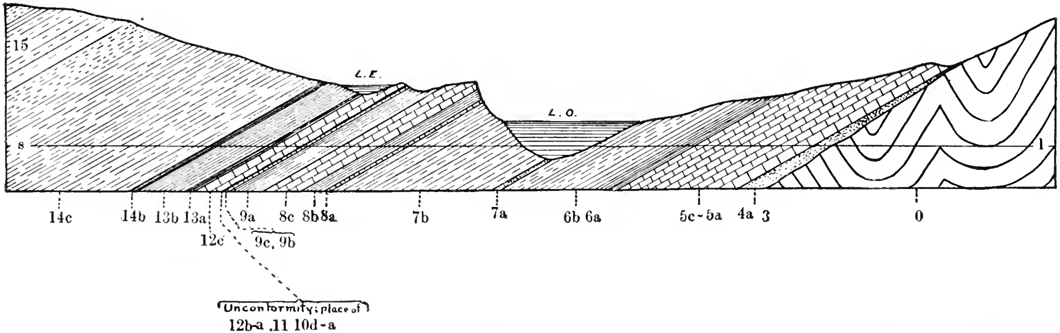


Fig. 1 Section from the Canadian highlands across western New York to the Pennsylvania line, showing the succession of strata. The numbering of the beds corresponds to that of the succeeding table. Owing to the great exaggeration of the vertical over the horizontal scale, the dip of the strata appears much too steep. s. l. = sea-level, L. E. = Lake Erie, L. O. = Lake Ontario. Horizontal scale 1 inch = 38 miles. Vertical scale, 1 inch = 1500 feet.

Table of Paleozoic subdivisions

Time scale	Formation scale	New York state rock equivalents	Thickness in the Niagara region
Paleozoic time	*Paleozoic system*		
5 Carbonic era	5 Carbonic series		
c Neocarbonic period	*c* Upper Carbonic group	Absent in New York	......
b Mesocarbonic period	*b* Middle Carbonic group	"	......
a Paleocarbonic period	*a* Lower Carbonic group	"	......
4 Devonic era	4 Devonic series		
c Neodevonic period	*c* Upper Devonic group	*c* Upper Devonic group	
		15 Chautauquan subgroup	?
		15a Chemung beds (Catskill sandstone, local facies)	......
		14 Senecan subgroup	
		14c Portage beds	
		3) Oneonta beds } local facies	
		2) Ithaca beds } local facies	938′ to 1541′
		1) Naples beds } local facies	
		14b Genesee shale	17′ to 25′
		14a Tully limestone	absent
b Mesodevonic period	*b* Middle Devonic group	*b* Middle Devonic group	
		13 Erian subgroup	
		13b Hamilton beds	76′
		13a Marcellus shale	211′
		12 Ulsterian subgroup	
		12c Onondaga limestone (including Corniferous)	108′ to 250′ ?
		12b Schoharie grit	absent
		12a Esopus grit	absent
a Paleodevonic period	*a* Lower Devonic group	*a* Lower Devonic group	
		11 Oriskanian subgroup	
		11a Oriskany beds	thin streaks of sandstone
		10 Helderbergian subgroup	
		10d Kingston beds (upper shaly)	absent
		10c Becraft limestone (upper Pentamerus)	absent

		10b New Scotland beds (Delthyris shaly)	absent
		10a Coeymans limestone (Lower Pentamerus)	absent
3 Siluric era	3 Siluric series		
c Neosiluric period	*c* Upper Siluric group	9 Cayugan group	
		9c Manlius limestone	7′ to 8′
		9b Rondout waterlime	60′
		9a Salina beds	386′
b Mesosiluric period	*b* Middle Siluric group	8 Niagaran group	
		8d Guelph dolomite	absent ?
		8c Lockport limestone (Niagara limestone)	200′ to 247′
		8b Rochester shale (Niagara shale)	70′ to 80′
		8a Clinton beds	23′ to 40′
a Paleosiluric period	*a* Lower Siluric group	7 Oswegan group	
		7b Medina sandstone	1266′ ±
		7a Oswego sandstone, Oneida conglomerate or Shawangunk grit	75′ ±
2 Ordovicic era	2 Ordovicic series		
c Neordovicic period	*c* Upper Ordovicic group	6 Cincinnatian group	
		6c [Richmond beds] absent	
		6b Lorraine beds; 6a Utica shale	630′
b Mesordovicic period	*b* Middle Ordovicic group	5 Mohawkian group	
		5c Trenton limestone; 5b Black river limestone	680 to 720′
		5a Lowville limestone (=Birdseye limestone)	absent ?
a Paleordovicic period	*a* Lower Ordovicic group	4 Canadian group	
		4b Chazy limestone	absent ?
		4a Beekmantown limestone (= Calciferous sandstone)	10′ to 110′
1 Cambric era	1 Cambric series		
c Neocambric period	*c* Upper Cambric group	3 Potsdamian group	
		3a Potsdam sandstone and limestone	10′ to 110′
b Mesocambric period	*b* Middle Cambric group	2 [Acadian]	absent
a Paleocambric period	*a* Lower Cambric group	1 Georgian group	absent
		1a Shales and limestones of Troy and Washington co. N. Y.	

Geologic map

A few words, descriptive of the accompanying geologic map may be added.

The topography is indicated chiefly by contour lines. These lines are 20 feet apart, and each connects the points which have the same elevation above sealevel. Thus wherever the 300 foot contour line occurs, every point along that line is supposed to be 300 feet above sealevel. The level of Lake Ontario is 247 feet above the sea; therefore the hight of any point above Lake Ontario can be calculated from the contours. Where the contours are close together, the slope of the country is steep; where far apart, it is gentle.

The various color patterns indicate what geologic formations would be shown on the surface of any given area, if the drift covering were removed. The beds of this region all dip gently southward; and, as we proceed northward, the lower beds rise from beneath the covering of the higher. Where steep cliffs occur, as in the gorge of the river or at Lewiston or Queenston, the lower beds crop out beneath the upper ones for only a very short space; hence they appear on the map as narrow color bands only. The character of the outcrops in the buried St Davids channel is only approximately delineated, to the extent indicated by well borings. It is probably much more irregular than is shown.

The outlines of the edges of the various beds from Lewiston eastward are taken from a map by G. K. Gilbert, the man who more than any other is identified with geologic studies at Niagara. The outcrops of the Onondaga and waterlime beds are taken from a map by Prof. I. P. Bishop. For the other outlines the author is responsible.

A few statistics[1]

Hight of American falls, Oct. 4, 1842	167.7	feet
" Horseshoe falls, "	[2]158.5	"
Mean total recession of American falls between 1842 and 1890	30.75	"

[1] Chiefly from the annual reports of the commissioners of the state reservation.

[2] The hights vary from 4 to 20 feet with the elevation of the water in the river below the falls.

Mean annual recession of American falls between 1842 and 1890	.64	feet
Mean total recession of Horseshoe falls between 1842 and 1890	104.51	"
Mean annual recession of Horseshoe falls between 1842 and 1890	2.18	"
Length of crest line of American falls in 1842	1080	"
in 1890	1060	"
" Horseshoe falls in 1842	2260	"
in 1890	3010	"
Total area of rock surface which has disappeared at the American falls between 1842 and 1890	32,900	sq. ft
or	.755	acres
Total area of rock surface which has disappeared at Horseshoe falls between 1842 and 1890	275,400	sq. ft
or	6.32	acres

These changes are graphically shown in the successive crest lines of the Horseshoe falls, given in fig. 19, p. 81.

Volume of water passing over the falls each minute[1]	22,440,000	cu. ft
or	1,402,500,000	pounds
or more than	7,000,000	tons

Depth of water in the channel of Niagara river below the falls[2]: (*see* fig. 18)

At foot of Horseshoe falls (center)	150 to 200	feet
Upper Great gorge, from the falls to the beginning of the Whirlpool rapids (from soundings)	160 to 190	"
Whirlpool rapids	35	"
Whirlpool	150	"
Outlet of whirlpool	50	"
Opposite Wintergreen flat	35	"
Below Foster's flats	70	"

[1]Blackwell. Am. jour. sci. 1844. 46 : 67.
[2]Estimated by Gilbert. Am. geol. 1896. 18 : 232-33 and elsewhere.

Width of Niagara gorge[1] (approximate):

Opposite the extreme west end of Goat island, and just in front of the Horseshoe falls	1250 feet
Opposite the center of the American fall	1700 "
Opposite inclined railway	1350 "
Between carriage and railroad bridges, narrowest point midway between the two	1000–1350 "
Just south of railroad bridges	950 "
Gorge of the whirlpool rapids	700–750 "
100 rods south of south side of whirlpool	1200 "
Same at water line	850 "
Inlet to whirlpool	1000 "
Same at water line	550 "
Outlet of whirlpool	900 "
Same at water line	450 "
South of Ongiara park	1300 "
Just south of Wintergreen flat	1600 "
River opposite Foster's flats (bottom)	300 "
Just south of Foster's flats (top)	1700 "
North of Devil's hole	1000 "
At the tunnel on the New York Central railroad (plate 12)	1300 "
Average width below Lewiston	2000 "

[1]Chiefly after Taylor. Bul. geol. soc. Am. 9 : 61-65. Top width is given unless otherwise stated.

Plate 3

The Niagara escarpment above Lewiston (inface of the Niagara cuesta). The lower plain (Ontario lowland) with Lewiston is seen on the left. The sandspit of the Iroquois beach is also shown. R. W. & O. railroad track in the foreground

Chapter 1

PHYSICAL GEOGRAPHY OF THE NIAGARA REGION

The physical geography of the Niagara region is of a relatively simple type, its main topographic features being readily interpreted. Unfortunately no very satisfactory birdseye view of the entire

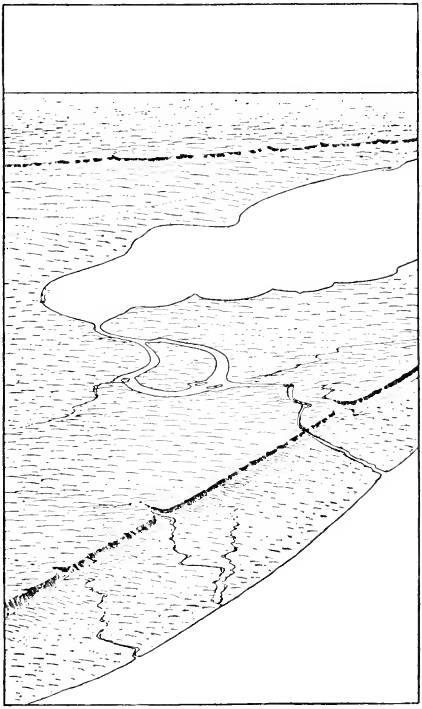


Fig. 2 Birdseye view of the Niagara region. (After Gilbert) The Niagara escarpment is shown in the foreground, with the lower plain sloping to Lake Ontario. The third upland belt is shown in the distance beyond Lake Erie. The second escarpment immediately north of Lake Erie, is not shown.

region can be obtained from any of the elevated points of the district; for the chief features are delineated on a scale too vast to be visible from a single vantage point. The best available spot from which a comprehensive view may be obtained is the summit of

Brock's monument, which commands the hights above Queenston, on the Canadian side of the river. Looking northward from this elevation, the observer sees an almost level plain, cut only by the winding lower Niagara, stretching from the foot of a pronounced and often precipitous escarpment to the shores of Lake Ontario, 7 miles away. Ordinarily the distant northern shore of the lake is not readily recognized by the unaided eye, though on clear days a faint streak of land may be seen between sky and water on the distant horizon. A good field glass however will generally disclose the opposite shore, and the much eroded cliffs of Scarborough. Far beyond these, fully a hundred miles to the north of the observer, the crystalline rocks of the Laurentide mountains rise from beneath their covering of Paleozoic strata, as formerly they rose above the waters of the Paleozoic sea. These ancient Canadian highlands, together with the Adirondack mountains of New York, and the old crystalline regions of the Appalachians, constitute the chief visible remnants of the old pre-Cambric North American continent. The erosion of these ancient lands has furnished much of the material from which beds of later date in this region were derived. Some of these beds may be seen in the sections cut by the rivers through the deposits in comparatively recent times, and no more instructive example than the gorge of the Niagara need be cited.

In the banks of the lower Niagara gorge may be seen the cut edges of the red shales and sandstones of the Medina group, the brilliant color of which is in striking contrast with the greenish blue of the water, and the darker green of the foliage which fringes its borders. The plain above is dotted with farms, orchards and hamlets, and is one of the richest agricultural and fruit districts of the country. In the foreground, on opposite banks of the river, lie the sister towns of Queenston and Lewiston, former rival guardians of the head of navigation of the lower Niagara, but now for the second time joined by bands of steel across the intervening gulf. Farther down the stream Niagara-on-the-Lake and Youngstown crown respectively the left and right bank of the river. These four towns of the lower Niagara, hold daily communication by ferry, steamboat or electric railway; the last and the steam railway keep-

ing them in touch with the cities of the upper Niagara and the world at large. This office is also performed by the well appointed steamboats which ply the lower Niagara, and carry passengers across Lake Ontario, to and from Toronto, the capital and metropolis of the province of Ontario. As these steamers enter or leave the Niagara river, they pass Forts Massassauga and Niagara which stand guard on opposite shores at the mouth of the river. The latter fort was established in 1678, and is rich in historic associations, while the Canadian fort is the modern successor of old Fort George, which was destroyed during the war of 1812.

When the observer on the Brock monument turns to the west or to the east, he sees the escarpment on which he stands, and the plain at its foot stretching in either direction beyond his field of view. The continuity of the escarpment is broken at intervals by ravines or gorges which dissect it, the most pronounced of these being the Niagara gorge in the immediate foreground. Westward from Queenston the escarpment is practically continuous for more than 3 miles, when, at the little town of St Davids, it is seen to recede abruptly, and a gap over a mile in width intervenes, beyond which it continues in force, with only minor interruptions, to Hamilton (Ont.), 40 miles west of the Niagara river. The gap at St Davids marks an ancient valley or gorge cut into the upland plateau which terminates at the escarpment. This old valley is traceable southeastward as far as the whirlpool, in the formation of which it has played a prominent part. It is filled throughout its greater extent by sand and clay, into which modern streams have cut gullies of greater or less magnitude.

Beyond St Davids, the escarpment, though indented by numerous streams, is as stated, continuous to Hamilton (Ont.). Here a larger and more pronounced interruption occurs, the escarpment being breached by a broad and deep channel, locally known as the Dundas valley. This ancient channel, with an average width of 2 miles or more, is traceable westward for a number of miles, when it becomes obliterated by drift deposits. Beyond the breach made by the Dundas valley, the escarpment continues in force, its direction however having changed to west of north, or nearly at right angles to its direc-

tion south of Lake Ontario. The eastern face of the Indian peninsula between Georgian bay and Lake Huron and the bold bluff of Cabot's head mark the northward extent of this escarpment, which, after an interruption by a broad transverse channel, is farther traceable in the northern slope of the Manitoulin islands. Eastward the escarpment continues to the vicinity of Lockport, where its continuity is interrupted by two pronounced gulfs, through one of which the Erie canal descends to the lowland of Lake Ontario. Beyond Lockport the escarpment becomes less pronounced; at first it separates into several minor steps or terraces and later it is replaced by a more or less continuous and gentle slope. Beyond the Genesee river it is no longer distinguishable, the surface of the country ascending gently and uniformly from Lake Ontario southward.

Turning now toward the south, the observer sees a second plain extending from the edge of the Niagara escarpment to where its continuity is blended with the horizon. This plain is not as uniform as the Ontario plain, which is fully 200 feet below it, and it is sharply divided by the Niagara gorge, from its northern edge at the escarpment to where, in the distance, a cloud of spray marks the location of the great cataracts. In the walls of the gorge can be seen the cut edges of the strata which enter into the structure of this higher plain, and attentive observation will reveal the fact, that the uppermost of these is a firm-looking limestone bed, which increases perceptibly in thickness toward the north. This thickening of the capping limestone bed, whose upper surface is essentially level, brings out a fact not otherwise readily noticed, namely that the strata all have a gentle inclination or dip to the south. The surface of the upper plain, aside from minor, mainly local irregularities, is essentially level, scarcely rising above the 600 foot contour line. This is the elevation, above the sea, of the base of Brock's monument, and it is the average elevation of the plain in the vicinity of Buffalo, the location of which, 20 miles to the south, is indicated by a perpetual cloud of smoke above the horizon.[1]

[1] A very satisfactory view of the level character of this plain is obtained during a ride by rail from Niagara Falls to Lockport, and thence by train or electric car to Buffalo.

For many miles to the east and west of the Niagara river the plain does not change perceptibly in elevation. Nevertheless, there is a gradual eastward descent, till, on the Genesee river, the surface of the plain, where not modified by superficial deposits, is fully a hundred feet lower than at Niagara. Westward the plain rises gradually, its elevation near Hamilton averaging 500 feet above Lake Ontario, or considerably more than 700 feet above the sea.

Owing to the southward inclination of the strata of this region, the limestone bed which forms the capping rock at the escarpment, eventually passes below the level of the plain, having previously increased in thickness to over 200 feet. The disappearance of the limestone as a surface rock occurs near the northern end of Grand island, as shown by the accompanying geologic map, and from this point southward the surface rock is formed by the soft gypsiferous and salt-bearing shales of the Salina group, which overlie the limestone and in turn pass below the higher strata in Buffalo, where beds of limestone again become the surface rock. Throughout the area where the shales form the surface rock, the plain is deeply excavated on both sides of the Niagara river, a longitudinal east and west valley, now largely filled by surface accumulations of sand and gravel, being revealed by borings. Tonawanda creek occupies this valley on the east, though flowing on drift, considerably above its floor, and Chippewa creek occupies it in part on the west of the Niagara river. This valley, as will be shown later, can be traced westward into Canada and eastward to where it joins the Mohawk valley, with which it forms the great avenue of communication across the state of New York. The northern boundary of the Tonawanda and Chippewa valleys is formed by a limestone cliff similar to, though less pronounced than, the Niagara escarpment. This cliff, generally known as the second limestone terrace of western New York (the Niagara escarpment being the first), is formed by the upper Siluric limestones (Waterlime and Manlius limestone) and the Onondaga limestone of the Devonic series. The latter is a very durable rock and hence it forms a very resistant capping stone. This escarpment is scarcely visible at Black Rock, where it is crossed by the Niagara river, for here it is low, and, in addition, extensive drift

accumulations have obliterated its topographic relief. Eastward and westward however it becomes prominent. A drive along Main street from Buffalo to Akron at the Erie county line will reveal the fact that it gradually increases in hight and boldness, till at the latter place it rises nearly a hundred feet above the Tonawanda valley, which itself is drift filled to a not inconsiderable extent. If we trace this escarpment into eastern New York, we find it progressively increasing in hight, owing to the interpolation, between the Manlius and Onondaga limestones, of the thick beds of the Helderbergian series, which, with the other lower Devonic beds, are entirely absent in the Niagara region, where their place is marked by an unconformity. (*See* figs.1 and 21-24)

If the observer changes his position to some elevated point near Buffalo, he may note that the plain which extends southward from the edge of the second escarpment, presents again a scarcely modified and almost level surface, which south of Buffalo gently descends to a third lowland, that of Buffalo creek and Lake Erie. Like the other lowlands, this one is carved out of soft rocks (Marcellus and Hamilton shales) and has subsequently been filled to some extent by drift deposits. This has been proved by borings which show that the bedrock in the valley of Buffalo creek is 83 feet below the surface of Lake Erie.[1] There are other excellent reasons for believing that the western end of this lowland, now occupied by Lake Erie, was once considerably lower than at present.

On the south the Erie lowland is defined by a range of hills, the northern edge of the great Allegany plateau, which forms the highlands of southern New York and northern Pennsylvania. There are no very pronounced declivities in the northern edge of this plateau in the Lake Erie region, owing no doubt to the relatively uniform character of the rocks composing it, there being no resistant capping bed of sufficient magnitude to produce an escarpment. Farther east, however, owing to the increasing thickness of the beds and their more resistant character, a prominent escarpment is developed, which near the Hudson unites with the escarpment of the lower series, and with it constitutes the prominent Hel-

[1] Pohlman. Life history of Niagara. 1888. p. 4.

derberg range, which culminates in southeastern New York in the high plateau of the Catskills. The Allegany plateau is everywhere much dissected by streams whose gorges have made the scenery of southern New York famous.

We have now seen that the topographic features of the Niagara district are arranged in a series of six east and west extending belts of alternating lowlands and terraciform elevations. The lowlands are the Ontario, Tonawanda-Chippewa, and Erie, the uplands are defined by the Niagara escarpment, the Onondaga escarpment and the hills of southern New York which constitute the northern edge of the Allegany plateau. The northern boundary of this belted country is formed by the old Canadian highlands.

We must now briefly consider the various strata of which the area under consideration is constructed, their origin, and the manner in which the topographic features of this region were produced. A brief review of the table of Paleozoic strata, given on pages 20 and 21, will be helpful to an understanding of the succeeding pages.

Development of the Paleozoic coastal plain

The Laurentian old-land is composed of rocks older than the Cambric period of the earth's history. These are largely of igneous origin, and such as were originally sediments have generally suffered much alteration through heat, pressure and other causes, and in most cases have assumed a more or less crystalline character. Though many of these pre-Cambric rocks may show apparent stratification, the present attitude of the beds does not often bear a close relation to their original condition. Indeed, these ancient rocks are generally much disturbed, their beds folded and flexed, and their laminae much contorted. Nor do the layers of the pre-Cambric rocks bear any normal relation to those of later date, the two series being wholly discordant with each other. The older beds are much worn, vast portions of the ancient folds having been swept away by erosion, and on the truncated edges of the remaining portions the newer strata were deposited in an essentially horizontal position. This *unconformity* of relation between the newer and older strata is a marked feature wherever the two series are ex-

hibited in contact with each other. Generally the older rocks have been worn down to an undulating plain (or peneplain), and the succeeding beds made from the fragments which were worn from the old land.

In the area under consideration, the ancient erosion surface of pre-Cambric rocks was overspread by a deposit of sand and occasionally gravel, which commonly possesses characteristics pointing to a very local origin. Thus the pebbles found in the lowest layers of the covering sands, i. e. the Potsdam sandstone, are sometimes of the same lithic character as the crystalline rocks near by. The Potsdam sandstone is a shallow-water rock, and during its accumulation a progressive subsidence of the sea floor took place, thus allowing the deposition of beds of considerable thickness. This subsidence brought with it a northward migration of the shore line of the sea, so that the region of the former coast line gradually became more remote from the shore. As a consequence, land-derived material became less abundant in this off-shore district, being deposited mainly along the new coast line, while farther out to sea calcareous deposits, resulting in part from the shells of organisms, became relatively more abundant. A profile through the strata of this region, such as would be obtained in a well or shaft sunk to the crystalline floor, would show a progressive decrease in the land-derived, or terrigenous material from the Potsdam sandstone upward to the top of the Trenton limestone, and a correspondingly progressive increase in the amount of calcareous matter. This indicates a sustained subsidence of the sea floor, and hence a migration of the shore with its attendant terrigenous deposit. It will also be seen that the lithic character of any particular formation is not the same throughout its extent, but that the local characteristics, or *facies*, show considerable variation. Close to the shore each formation would present a terrigenous character, i. e. would show gravelly, sandy or clayey facies, while away from shore each formation would pass into its calcareous facies, which would increase in purity with the increase in distance from the source of supply of terrigenous sediment. Thus the Potsdam formation has calcareous as well as sandy facies, with facies of intermediate type connecting them.

The Utica shales and the arenaceous Lorraine shales which follow on the Trenton limestones show a return of land-derived deposits due probably to a shoaling of the water. This may have been caused by an upward movement of the sea bottom or by a partial withdrawal of the water into deepening oceanic basins. Some abrupt change is indicated by the sudden transition from limestone to black shale. Another abrupt change occurred at the close of the Ordovicic era, as indicated by the marked contrast between the Lorraine shales and the Oneida and Medina beds which immediately succeed them.

The Siluric deposits of this region began as shallow water accumulations, the lowest bed being the Oswego sandstone, which farther east, is replaced by the conglomerates of Oneida county and the Shawangunk range. The marls and shales of the Medina series succeed these sandstones with an aggregate thickness exceeding 1100 feet. A heavy stratum of gray quartzose sandstone, varying in thickness up to 25 or 30 feet, separates, in the Niagara region, the lower from the upper Medina shales and sandstones, which have an approximate thickness of 100 feet. The Clinton shales and heavy limestones follow on the Medina, with a thickness averaging 30 feet. The Rochester shales, with a thickness of 60 to 70 feet, follow the Clinton limestones and are in turn succeeded by the Lockport limestone, whose average thickness, obtained from well records, approximates 250 feet in this region. The Salina shales succeeding the Niagara beds (Rochester shales and Lockport limestone) have an aggregate thickness of less than 400 feet, and are followed by the Waterlime and the Manlius limestone, the former averaging 50 feet in thickness, the latter from 7 to 8 feet. The lowest Devonic beds are absent in this region, the Onondaga limestone resting directly on the Manlius beds, there being, as before noted, an important though not very pronounced unconformity between the two. A glance at the geologic map of this region will reveal the fact that the lower strata rise from under the covering newer beds on the north, and occupy a belt of country of greater or less width according to the thickness of the beds. Where they come to an end, the next lower beds make their appearance. The discontinuation of the higher

beds northward is due to a thinning out of the exposed portion of the strata, as can be readily seen in the Lockport limestone bed, which is less than 30 feet thick at Lewiston, but more than 80 feet at the falls, increasing in thickness southward to 250 feet or more. Where, however, the strata are not exposed on the surface, i. e. where they are only shown in sections under cover of the overlying rock, no such thinning is seen. This may be observed in the case of the Clinton beds and the upper Medina sandstones. In some cases these beds are seen to even thin southward, as proved by borings. The thinning of these strata does not, as is often assumed, mark the original thinning of the beds toward the shore on the north, but is evidently due to erosion. A brief résumé of the origin of the various strata will make this clear.

The Medina sandstone is an ancient shore and shallow water deposit, as will be more fully pointed out in chapter 3. The sands and gravels, which with some finer muds, make up this rock, are all derived from some preexisting land. The only source of supply was the old Laurentian land on the north and the Appalachian old-land on the south. It is true that, owing to the elevation at the beginning of Siluric time, some of the pre-Siluric stratified rocks may have been raised above the sealevel and added to the old-land, and that part of the Medina sands may have been derived from these. Even then the largest amount of detritus was probably derived from the crystalline old-lands, the progressive accumulation of 1200 feet of Medina rock marking a corresponding subsidence and a concomitant encroachment of the seashore of the Medina sea on the old-land. Thus the Medina deposits gradually overlapped the Ordovicic and Cambric deposits and probably eventually came to rest entirely on the crystalline pre-Cambric rocks. Continued subsidence, at least in the Niagara region, produced the purification of the water, so that eventually the limestones of the Clinton epoch could be formed in a region remote from that in which terrigenous material was accumulating. This was likewise true of the Lockport limestone, which was deposited after an interval, during which the calcareous shales separating the two limestone series accumulated. While

these deposits, particularly the limestones, point to a considerable distance from the shore line, we are by no means at liberty to assume that no shore formations accumulated during this period. In fact, it would be difficult to understand the non-accumulation of terrigenous material along the shores of any land during any period of the earth's history unless such land was without even moderate relief. As will be shown in chapter 3 there are reasons for supposing that a considerable land barrier existed in the north as well as the east and southeast, and thus we may assume that shore deposits of terrigenous material were formed while the limestones were accumulating in the clearer waters. That the shores of this period did not consist of Medina sandstone is indicated by the absence of any such material in the shales of either the Clinton or Niagara series. It is highly probable that the shore was still formed by the old crystalline highlands, and that the accumulating Clinton and Niagara sediments overlapped and completely buried the Medina beds. The limestones are chiefly fragmental in origin, being composed of calcareous and magnesian sands. These, as will be shown later, were largely derived from the destruction of coral reefs and shells growing in the immediate neighborhood. They indicate shallow water, a conclusion emphasized by the occurrence of well marked cross-bedding structure in some of the beds of limestone. We may assume a gradual passage from pure calcareous beds to beds consisting more and more of terrigenous detritus as we approach the old shore line, where quartz sands probably constituted the chief material of the deposits.

We may obtain an approximate indication of the former extent of these strata if an attempt be made to restore the portions which must have been removed by erosion. We may consider the Clinton and Niagara as a unit, assuming that near the old shore their beds were practicably indistinguishable. The average dip of the strata of this region is 25 feet to the mile (a moderate estimate, as the dip ranges up to 40 feet), and the base of the Clinton-Niagara is approximately 400 feet above sea level. Continuing this dip northward for a hundred miles to where the present borders of the oldland are exposed, the base of this group would have risen 2900 feet

above the sea, an elevation sufficient to overtop the highest peak of the present Laurentides; for, according to Logan, "in the country between the Ottawa and Lake Huron the highest summits do not appear to exceed 1500 or 1700 feet, though one . . . probably attains 2300 feet".[1] We assume of course with good reason that the Laurentides at that period were much higher than now, for they must have suffered enormous erosion during the long interval since the close of Siluric time.[2]

Since the deposition of these Siluric strata the region under consideration has suffered an enormous amount of denudation, having been brought to the condition of a low nearly level tract or *peneplain*, but little above sea level, not once, but probably a number of times, separated by periods of elevation and at least one of sub-

[1] Logan. Geol. Canada. 1863. p. 5.

[2] The Niagara beds of Lake Temiscaming, in the great pre-Cambric area of Canada and 150 miles distant from the nearest beds of the same age, are of interest in this connection. They occupy an area about 300 miles due north of Lewiston and on the north side of the present Laurentide chain. According to Logan they do not properly belong to the former extension of the Niagara beds of the region under consideration, but rather to the Hudson bay area on the north. They are of interest however as showing the great former extent of these formations. They lie unconformably on the pre-Cambric rocks, and the basal members are generally sandstones and often conglomerates "containing large pebbles, fragments, and frequently huge boulders of the subjacent rock" (Logan, p. 335). The thickness of the formation here is estimated at between 300 and 500 feet. The Ordovicic and Cambric strata are absent, showing a progressive encroachment of the sea on the old-land, and a consequent overlapping of the strata. Outliers of earlier strata are found in more southern portions of Canada, resting on the pre-Cambric surface, and many of these indicate a progressive overlapping of later over earlier beds. Lawson holds that this indicates, that most of the Canadian old-land was covered by the early Paleozoic strata, and that erosion since Paleozoic time has resulted in simply removing these overlying rocks. (Bul. geol. soc. Am. 1 : 169 et seq.) He holds that comparatively little erosion of the old-land has occurred since Paleozoic time, the present surface being essentially pre-Cambric and only revealed by stripping of the overlying rocks. It is not improbable however that some of these distant outliers may have been preserved during the extensive denudation of the old-land, by having been faulted down previously in a manner well known to have occurred in the Scandinavian old-lands, a solution suggested to me by my friend, A. W. G. Wilson, of Harvard university.

sidence. The present surface of the Niagara plateau is therefore not to be considered as identical with the old surface of deposition, but as due to prolonged peneplanation, or erosion to near sealevel, completed probably toward the close of Mesozoic or the beginning of Cenozoic time. The following diagram (fig. 3) will illustrate the relation between the strata and the surface of the land at 1) the close of Siluric time, 2) late Mesozoic or early Cenozoic time, after the completion of the last cycle of erosion and the reduction of the land to peneplain condition, and 3) the present surface.

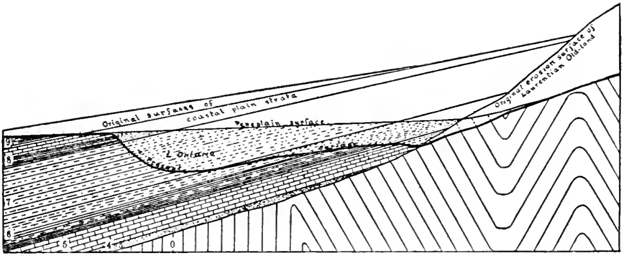


Fig. 3 Diagram of ancient Paleozoic coastal plain, and its relation to the Mesozoic peneplain surface and the present land surface. The numbering of the beds corresponds to that of the table.

Between the close of the Siluric and beginning of Mesozoic time a long period intervened, during which this region was at first a land surface, suffering considerable erosion, but later was resubmerged, and covered with extensive deposits of Devonic limestones, shales and sandstones. The final emergence took place at the close of Paleozoic time, the succeeding Mesozoic time being in this region probably an uninterrupted period of erosion, during which the land suffered the combined attacks of the atmosphere and of running water.

Development of the drainage features

The water which falls as rain or snow on the land either evaporates, runs off on the surface, or sinks into the ground, where it constitutes the ground water. That which evaporates, accomplishes little or no direct geologic work, but both the surface and underground waters are important geologic agents. If the surface on which the water falls is a perfectly smooth but inclined plain, the water will run off in the form of a thin sheet. A perfectly smooth

land surface is however unknown, and the run-off of the surface waters is always concentrated along certain lowest lines, thus constituting brooks, streams and rivers. While there may be numerous drainage lines of this type, they generally unite into a few master streams, the direction of whose flow is down the inclination of the surface of the land. Such streams are known as *consequent* streams, their direction of flow being consequent on the original slope of the surface.

When the strata of the Niagara region became a part of the dry land, from the relative lowering of the water level (which may have been due to rise of the land or to drawing off of water by the deepening of the oceanic basins), they formed a broad, essentially monotonous belt of country fringing the old-land on the north, i. e. a marginal coastal plain. The strata of this plain had a gentle southward inclination, a feature shared by the surface of the plain. Consequent streams quickly made their appearance on this plain, a number of them probably coming into existence almost simultaneously and running essentially parallel from the old-land, across the new coastal plain into the sea. These streams soon cut down into the coastal plain, carving channels for themselves and thus establishing definite lines of drainage. As the streams at first consisted entirely of the run-off of the moisture which fell on the plain and in the higher old-land portion, it is evident that, unless the rainfall was continuous, or unless extensive snow fields were present to supply water, these young streams must have fluctuated greatly in volume of water, and at intervals become entirely dry. This condition continued till the valleys, cut by these streams of run-off water, had become sufficiently deep to reach the level of the underground water, when the supply, augmented by springs, became much more constant. Thus in course of time large valleys, supplied with large rivers, came into existence. Meanwhile the sides of the river valleys were attacked by the atmosphere, and degradation of the cliffs cut by the stream resulted.

As long as a river is narrow and vigorously undercuts its banks, the latter will be steep, and the river channel will have the character of a gorge. This generally continues as long as the river is cutting

Plate 4

American and Luna Falls from below, with limestone fragments fallen from the cliff above (Copyright by Underwood & Underwood, New York)

downward, i. e. till the grade of the river bottom is a very gentle one, when lateral swinging widens the gorge by undercutting the banks, and atmospheric degradation quickly destroys the steep cliffs which the river does not keep perpendicular.

During the process of drainage development, numerous side streams come into existence, which join the main stream as branches. These begin as gullies formed by the rainwater running over the sides of the banks into the main stream. A slight depression in the surface, or a difference in the character of the material composing the banks, may determine the location of such a gully, but, once determined, it will become the cause of its own farther growth. For the existence of this gully will determine the direction of flow of succeeding surface waters, and so in the course of time the gully will become longer and longer by headward gnawing, till finally a channel of considerable magnitude is produced. Streams of this type are known as *subsequent* streams, and they very generally have a direction varying from a moderately acute to nearly a right angle with reference to the main or consequent stream.

As the dissection of the Niagara coastal plain continued, the higher portions of the strata, i. e. those nearer the old-land, were slowly removed, and the beds lying beneath these were thus exposed. The latter strata were generally of a more destructible character than the overlying ones, and on this account great lowlands, parallel to the old shore line, or the line of strike of the strata, were worn in them by subsequent streams. The more resistant beds, meanwhile, favored the formation of more or less prominent cliffs or escarpments which faced the lowlands, and being undermined slowly retreated southward, thus increasing the width of the lowlands. These features are today repeated in the Niagara escarpment which faces the Ontario and Georgian bay lowlands, and the escarpments formed by the outcrops of the Ordovicic limestones farther north. The diagram, fig. 4, illustrates the probable condition during early Mesozoic time. The great master consequent streams indicated are: the Saginaw, the Dundas and the Genesee, flowing from the old-land on the northeast, southward or southwest-

ward into the Mesozoic interior sea. There were probably other consequent rivers, whose location may be in part indicated by some of the valleys now occupied by the Finger lakes of New York. Subsequent streams, flowing along the strike of the beds and capable of accomplishing much erosion by undermining the resistant capping beds of the escarpments, continued to widen the longitudinal (i. e. eastwest) lowland areas, while the transverse valleys of the consequent streams remained relatively narrow.

The topographic relief feature produced by this normal development of drainage on a young coastal plain consisting of alternating harder and softer strata, has been named a "cuesta",[1] and may be briefly defined as an upland belt of slightly inclined coastal plain strata, with a surface gently sloping toward the newer shore, and a steep escarpment, or *inface*, fronting a low belt, or *inner lowland*, which separates the cuesta from the old-land upon which its strata formerly lapped. The existence of the cuesta form is usually due to a more or less resistant stratum overlying a less resistant one, as, for example, the limestones overlying the upper Medina shales. The inface of the cuesta is continually pushed back by the undermining subsequent streams, aided by atmospheric attack, and thus the belt of low country, lying between the cuesta and the old-land, is continually widened, while during the same time the valley of the transverse consequent stream which carries out the drainage increases comparatively little in width. It must be remembered however that the lowland can never be deepened below the depth of the valley of the consequent stream which carries its waters through the breach in the cuesta.

While the main drainage of this region was undoubtedly southwestward by consequent streams, which flowed through the cuesta in gorges, and by subsequent streams flowing into the former, and occupying the inner lowlands, short streams, flowing toward the old-land, down the inface of the cuesta, were probably not uncommon. These streams began to gnaw gullies back from the inface

[1] Davis, W. M. Science. 1897. New series. 5:362; *also* Textbook of physical geography. 1899. p. 133. Pronounced kwesta, a word of Spanish origin "used in New Mexico for low ridges of steep descent on one side and gentle slope on the other".

of the cuesta, and ultimately prolonged these gullies into gorges, and carried the drainage into the subsequent streams. Streams of this type, which have their representatives in all coastal plain regions, have been called *obsequent* streams,[1] their direction of flow being opposite to that of the consequent streams. The following diagram (fig. 4) illustrates this type of a stream and its relation to the subsequent and consequent streams. To this type of stream belongs the ancient St Davids gorge, as will be shown more fully in subsequent pages.

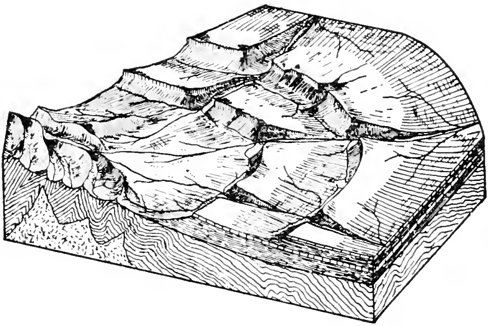


Fig. 4 Diagram of a portion of a dissected coastal plain, showing old-land on the left, and two cuestas with their accompanying inner lowlands. Three consequent streams have breached the cuestas, and subsequent streams from the lowlands join them. An obsequent stream is shown in the center of the outer cuesta.

If we assume that during the greater part of the Mesozoic era, the land in this region remained in a constant relation to the sea-level, it becomes apparent that the southward retreating infaces of the cuestas formed by the resistant members of the Paleozoic rocks, became lower and lower, as the southward inclination of the strata carried the resistant beds nearer and nearer to sealevel. Eventually the escarpment character of the infaces must have become obsolete, from the disappearance, beneath the erosion level, of the weaker lower strata, which permitted the undermining of the capping beds. When this occurred, the capping strata alone continued exposed to the action of the atmosphere, and, from a cliff character, their exposed ends were planed off to a wedge shape, thin-

[1] W. M. Davis

ning northward at a rate proportional to the dip of the beds. The ultimate result of all this erosion was the reduction of the land to a low peneplain, which did not rise much above the sealevel. Portions of this peneplain are today preserved in a scarcely altered condition, in the Niagara upland, the region about Buffalo and other localities. The slight change which these regions have subsequently undergone leads to the supposition that the peneplain was completed in comparatively recent geologic time, possibly at the beginning of the Tertiary era, or even more recently. This is also shown by the comparative narrowness of the valleys cut into the peneplain surface in preglacial times. The present altitude of this peneplain in the vicinity of the Niagara river is approximately 600 feet above sealevel, while southward it rises. There is however good presumptive evidence, some of which will be detailed later, that, during a period preceding the glacial epoch, the land in the north stood much higher than at present, so that the slope of the surface was southward. An accentuation of slope would cause a rejuvenation of the consequent streams, which, in the later stages of peneplanation, had practically ceased their work of erosion on account of the low gradient of the land. As a result of the renewal of erosive activity the early Mesozoic topography was in a large measure restored, but the inface of the Niagara cuesta, the top of which is now found in the Niagara escarpment, occupied in the restored topography a position considerably farther to the south than that characteristic of early Mesozoic time.

We may now examine more in detail the channels of the consequent streams which dissected this ancient coastal plain, and the extent of the inner lowlands drained by the subsequent streams tributary to them.

Dundas valley. The Dundas valley appears to have been the outlet for the master consequent stream of this region, the Dundas river. This valley, as before noted, breaches the escarpment at Hamilton (Ont.), near the extreme western end of Lake Ontario. The valley has been carefully described by Spencer, who considered it the pathway of the preglacial outlet of Lake Erie into Lake Ontario, the drainage of the Erie valley being in his opinion by a

river which followed the present course of the Grand river, above Cayuga, past Seneca and Ancaster into the western end of the Ontario valley. It is extremely doubtful that such a stream ever existed, certainly it is highly improbable that the Dundas valley owes its existence to any stream which flowed eastward or toward the old-land, for it is altogether too broad, and continues too uniformly to permit its being regarded as the valley of an obsequent stream. Moreover, its peculiar position at the elbow of the escarpment is most suggestive of a consequent origin, for we would expect the face of the cuesta to make a reentrant where the master stream gathers its converging tributaries and flows out through a great breach in the cuesta.

The Dundas valley is 5 miles wide at Hamilton but rapidly decreases in width to 2 or $2\frac{1}{2}$ miles at the top, where the limestone forms decidedly sharp summit angles (Spencer). Its northern wall has been traced westward for 6 miles to Copetown, and its southern for $3\frac{1}{2}$ miles to Ancaster. Beyond these points the valley is filled with drift which has been much dissected by modern streams. The axis of the gorge is about n 70° e, and the glacial scratches observed on the rock surfaces at its summit, with few exceptions, make angles of 30° or more with it (Spencer).

At Hamilton the bedrock was found to be absent to a depth of 227 feet below the surface of Lake Ontario. The well from which this record was obtained is about 1 mile distant from the southern side of the Dundas valley, which is here 5 miles wide. The total known depth of the canyon is, according to Spencer, 743 feet, but he calculates that it reaches 1000 feet near the center.[1] Along the northern shore of Lake Erie well records have shown the absence of drift to a considerable depth. Thus, according to Spencer, at Vienna, 100 miles due west of Buffalo, the drift is absent to a depth of 200 feet below the surface of Lake Erie, while at Port Stanley, 20 miles farther west, it is absent to a depth of 150 feet below the lake. At Detroit the drift is 130 feet deep. At St Marys on the northwest and Tilsonburg on the southeast of a line connecting

[1] Spencer. Pa. geol. sur. Q 4. p. 384-85.

Port Stanley with Dundas, Devonic limestones occur at a considerable elevation above Lake Erie (Spencer). Hence the southwestward continuation of the Dundas channel must be placed between

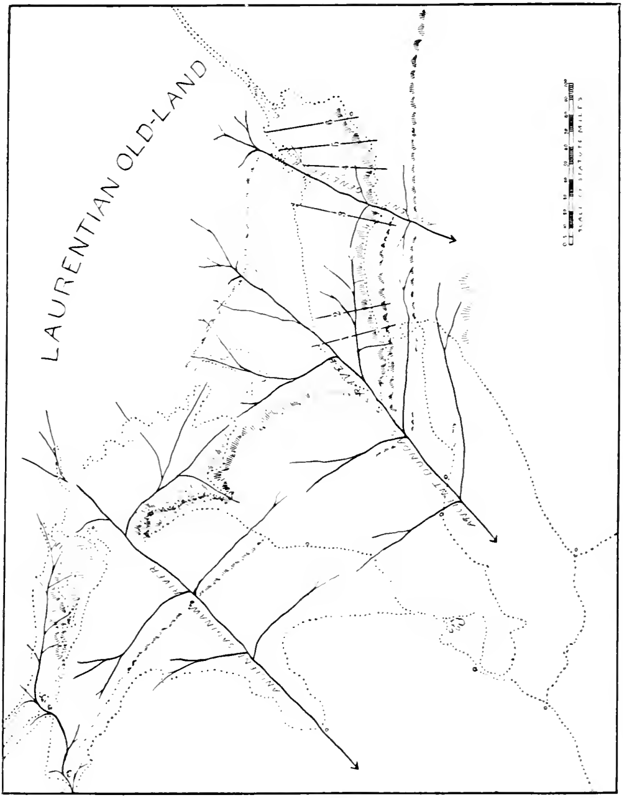


Fig. 5 Diagram showing type of drainage existing in Tertiary times in the Laurentian region.[1]

[1]These maps are intended merely to illustrate the *kind* of drainage, which it is believed existed in preglacial times in the Laurentian region. The ancient consequent streams are probably correctly located; yet it must be stated that the region between Hamilton and Port Stanley has not been sufficiently explored to make the course indicated certain. These consequents may have had a more indirect course, for if the country was worn down to peneplain condition, as appears to have been the case, these streams may have learned

these two points. On the southern shore of Lake Erie borings have revealed numerous deep channels. Thus the bottom of the ancient channel of the Cuyahoga river is reached, according to

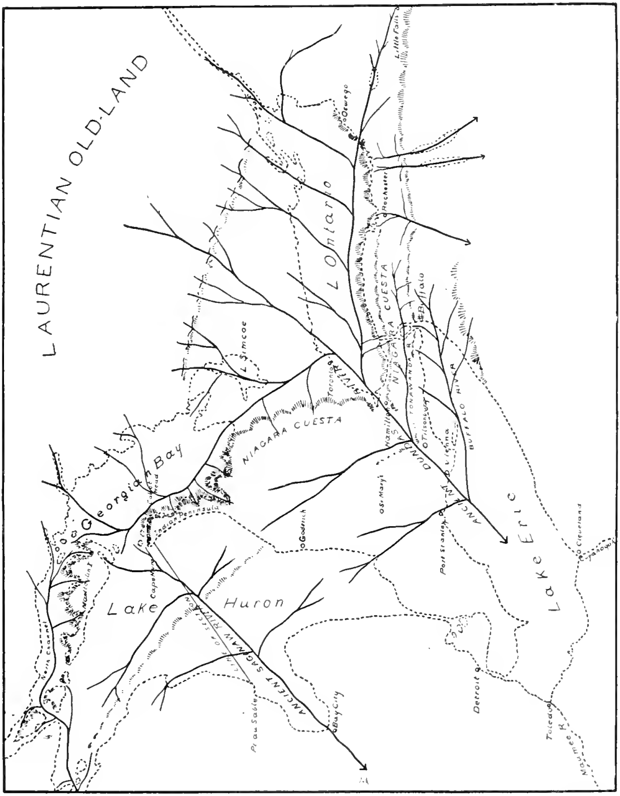


Fig. 6 A hypothetic later stage, showing adjustments which are suggested by existing relief features.

to meander on this surface, the meandering course being retained on re-elevation. The depth of the bed rock at Port Stanley and Vienna, however suggests that a direct channel exists as shown on the map. The principal subsequents are probably located with approximate correctness, but the smaller branches are added without attempt at correctness. They were probably much more numerous than here shown.

Upham,[1] at a depth of more than 400 feet below Lake Erie. Whether this marks the former southward continuation of the preglacial Dundas river or whether that river turned more to the west, following in general the course of the present Maumee, must for the present remain unsettled. The Dundas undoubtedly became eventually tributary to the Mississippi.

Preglacial Saginaw river. The existence of an ancient river, flowing southwestward from the Canadian old-land across the valley of Lake Huron and the lower peninsula of Michigan, and finally becoming tributary to the ancient Mississippi, is indicated by the present character of the topography of that region. The Niagara cuesta is breached by a deep channel which now connects Georgian bay with Lake Huron, and which, north of Cove island, an outlier from the Indian peninsula, has been sounded to a depth of over 300 feet. This channel is in direct line with that of Saginaw bay, and, though this latter is at present very shallow, borings at Bay City show an absence of rock to a depth of at least 200 feet below the surface of the bay. At Alma (Mich.) the rock was shown to be absent to a depth of 350 feet below Lake Huron (Spencer); and, as this locality lies to the southwest of Saginaw bay and in line with the trend of its axis, we may assume that our preglacial Saginaw river was located here. Our limited knowledge of the preglacial topography of this region forbids tracing this channel beyond this point. Dr Spencer many years ago traced out this line of drainage, but he assumed that the river which occupied this channel, and which he has named Huronian, flowed northeastward to join that part of the ancient St Lawrence, or Laurentian river, which he supposed to have occupied Georgian bay.

Preglacial consequent Genesee river. Among the numerous consequent streams which flowed from the old-land southward or southwestward and which eventually became tributary to the preglacial Mississippi, probably through the ancient Ohio,[2] the pre-

[1] Bul. geol. soc. Am. 8: 7.

[2] Westgate, Lewis. Geographical development of the eastern part of the Mississippi drainage system. Am. geol. 1893. 11:245-60. The Ohio, according to Newberry, flows nearly throughout its entire course in a channel, the rock bottom of which is nowhere less than 150 feet below the present river. The rocks at the "falls of the Ohio" show that at that point the river is not following the ancient course.

glacial Genesee river is the only other that can be mentioned here. Though now flowing northward on account of the tilting of the land, we may assume that much of its valley was carved by a southward flowing stream, the bottom of which, as shown by borings, was considerably below the floor of the present river. Whether Irondequoit bay is a part of this ancient channel, or whether it marks the position of an obsequent stream, must remain for the present an open question. Soundings in Irondequoit bay show a depth of 70 feet, though the rock bottom is probably much deeper.

As soon as the consequent streams began cutting down their valleys again after the continental uplift which followed the period of peneplanation, the lateral subsequent streams began once more to open out broad lowlands in the weaker beds which now had become extensively exposed. These lowlands, in part now filled by drift deposits, are the Ontario and Georgian bay valleys, the latter continued in the North Passage, all carved out of the weak Medina and Lorraine shales; the Tonawanda-Chippewa valley, with the deeper portion of the Huron valley farther west, carved out of the soft shales of the Salina group; and the valley of Lake Erie cut out of the softer middle and upper Devonic shales. A few of these may be considered in greater detail.

Ontario valley. It is a well known fact that Lake Ontario is deeper in its eastern than its western part. In the following six cross-sections (fig. 7), constructed from the lake survey charts, the greatest depths from west to east are 456, 528, 570, 738, 684 and 576 feet. The section showing the greatest depth is that from Pultneyville to Point Peter light, in the eastern third of the lake. As the present level of Lake Ontario is 247 feet above the sea, the deepest sounding recorded in these sections is 491 feet below present sealevel. From this point of greatest depth, the floor of the lake rises eastward, at first at the rate of 3 feet in the mile, and later at an average rate of 9 feet a mile. The valley appears to be continued south of the Adirondacks in New York along the present course of the Mohawk river, which flows at present several hundred feet above the rocky floor of the valley.[1] This floor ascends eastward, till at Littlefalls

[1] Carll. Pa. geol. sur. I^3:363.

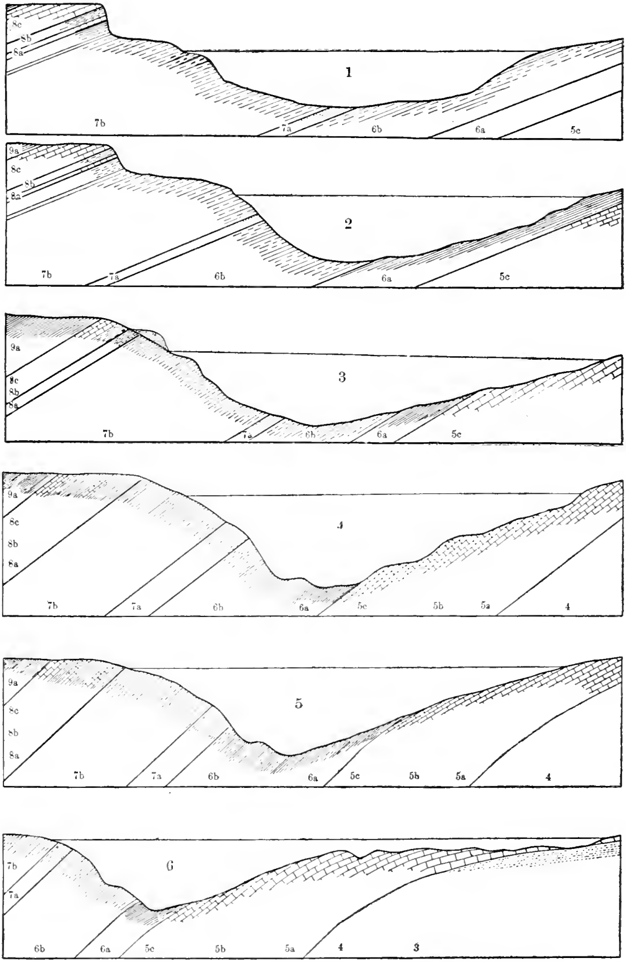


Fig. 7 Six cross-sections of Lake Ontario showing topography and geology. Vertical scale 1 inch = 1280 feet; horizontal scale 1 inch = 15¾ miles. Numbering of beds as in table; location of sections indicated in fig. 5. Section 1) E. of Niagara to E of Pickering light. 2) Lockport to Darlington light. 3) West of Genesee to Presque Isle light. 4) Pultneyville to Point Peter. 5) West of Fair Haven light to False Buck light. 6) Oswego to Kingston.

the preglacial divide has an elevation of 440 feet above sealevel.[1] The following diagram (fig. 8) shows the present relation of the deepest part of the channel of Lake Ontario to sealevel, and the relation which would result by a tilting of the land back to its probable position in preglacial times. The last profile shows a continuous westward slope of the floor of the valley, steeper in the eastern portion, where the rocks are harder and the valley narrower, and more gentle in the western portion, where the softer rocks have allowed the opening of a broad lowland.

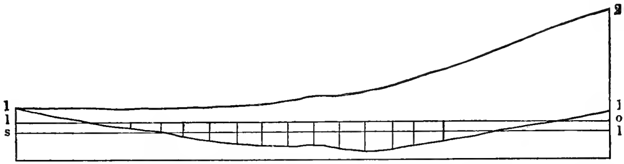


Fig. 8 Diagram showing the present deepest e–w channel of Lake Ontario along line 1–1, and its relation to sealevel s. l. and the level of Lake Ontario l o. At 1, left side of diagram is represented the bottom of the channel at Vienna, 200 ft below level of Lake Erie or 370 ft above sealevel. At 1, right side, is the divide at Littlefalls 440 ft A. T. The line 1–2, is the line 1–1, but elevated on the east (right) so as to give a continuous westward drainage. Horizontal scale 1 inch = 100 miles. Vertical scale 1 inch = 4000 feet.

Numerous theories have been advanced to account for the deep basin of Lake Ontario. Spencer believed it to have been formed by an eastward flowing stream, the ancient Laurentian river, which received the Erian river as a tributary through the Dundas valley. The eastward continuation of this river Spencer believed to have been essentially along the course of the modern St Lawrence, the present great elevation of the rocky bed of this stream, above that of Lake Ontario, being explained by a warping of the land. Upham also believes that the basin is in part due to warping, but he considers it the valley of a westward flowing stream. Russell also holds this latter view; for he says[2] that, "previous to the glacial epoch, the greater part of the Laurentian basin discharged its waters southward to the Mississippi and . . . during the first advance of the ice from the north the drainage was not obstructed so as to form important lakes". Westgate[3], in tracing out the de-

[1] Bigelow. Bul. geol. soc. Am. 9·183.
[2] Lakes of North America, p. 97.
[3] *Loc. cit.* p. 92.

velopment of the Mississippi drainage system, considers that the flow of the Laurentian drainage system was southward into the predecessor of the Ohio river. As has already been shown, Spencer's eastward flowing river system can be originated only by a complete readjustment of the drainage, resulting from a great relative depression of the eastern uplands. Such a system could only come into existence after the valleys had been formed for it, and hence, as far as the history of the lake basins is considered, no such river system is required, and, unless positive proof of its former existence is forthcoming, it may be dismissed as hypothetic. One of the most important theories of the origin of the Ontario and other lake basins, and one which has had, and still has many prominent advocates, is that of glacial erosion, either entire or preceded by river erosion. This explanation was first most strongly urged by Prof. Newberry, and it has found its most recent able supporter in Prof. Tarr. It is impossible to do full justice to this view in the present limited space. Ice erosion is a factor the potency of which has often been overlooked, but of the importance of which there can be no question. We may however question whether a valley which, like that of Ontario, lies transverse to the general direction of ice movement in this region, can owe much of its depth to this agent. The following considerations will be helpful in understanding the influence of glacial erosion on preexisting topography. If a valley like that of Lake Ontario is occupied by a glacier the motion of which is parallel to the trend of the valley, the topographic relief is likely to be accentuated by ice erosion. If the motion of the ice is transverse to the direction of the valley, the erosion tends to obliterate or at least reduce the relief features. If, however, a mass of ice remains stagnant in the valley, the upper strata of ice may override it, and the amount of glacial erosion is reduced to a minimum. The striae in this region, together with the direction of slopes from the oldland, point to a southward movement of the ice, and Gilbert has shown that the amount of erosion on the edge of the escarpment in western New York is comparatively slight.[1] Hence we may assume that the basin of Ontario was mainly *occupied* by ice during the

[1] Bul. geol. soc. Am. 11:121.

glacial period, but that comparatively little erosion was accomplished. This is farther borne out by minor relief features, such as the benches shown in sections 4, 5 and 6, in the southern wall of the basin, and which probably consist of harder beds which erosion has left standing out in relief. On the theory of glacial erosion, we might expect these to be absent, or at least much less prominent, since ice would hardly show such selective power as is attributable to running water and atmospheric agents.

With the failures of the theories that an eastward flowing stream or glacial ice produced the Ontario valley, we are forced, with Upham, Russell and others, to look on a westward flowing stream as the most probable agent in the production of this valley. As has before been shown, such a stream would be the normal result of a gradual development of a drainage system on an ancient coastal plain of the type here considered.

Ancient St Davids gorge. Since the time of Lyell, the old buried channel from the whirlpool to St Davids has played a prominent part in the discussion of the life history of Niagara. For a long time it was considered to be the preglacial channel of Niagara, or its predecessor, the Tonawanda. More recently it has been considered of interglacial age, eroded by an interglacial Niagara, during a temporary recession of the ice sheet from this region, and filled with drift during a readvance of the glacier. The most satisfactory interpretation of this channel however makes it independent of the Niagara, and considers it one of many preglacial or interglacial channels which were formed by streams flowing over the edge of the escarpment and which increased in length by headward gnawing of their waters. This type of stream we have learned to call *obsequent*, its direction of flow being contrary to that of the master stream to which its waters eventually become tributary. An illustration of channel-cutting by streams flowing over the edge of a cliff, may be seen today in the chasm near the Devil's hole, on the American side of the gorge below the whirlpool. This gulch was cut by the little stream known as the Bloody run, which during the summer season dries away entirely.

The St Davids gorge has a width of nearly 2 miles at the edge of the escarpment. As will be seen by a glance at the map, it nar-

rows perceptibly southward, till at the whirlpool its width is less than the average width of the Niagara gorge. What the depth of the gorge is has not been determined, though from the depth of the whirlpool, we may assume that its floor is 200 feet or more below the level of Lake Ontario. At, and to the north of the escarpment it probably equals in depth Lake Ontario, opposite to it. The channel is undoubtedly much more irregular than is shown on the map, the sides being probably much diversified by lateral gullies. The great width of the channel at St Davids may perhaps be due in some small degree to widening by glacial erosion; for we know that the channel was occupied by ice, from the glacial scratches which are preserved on its walls, where these are exposed in the present ravine of Bowman's creek near the whirlpool. The influence of this buried channel on the direction and width of the Niagara gorge will be discussed later.

Valley of Georgian bay. Georgian bay is in many respects the analogue of Lake Ontario. Like the latter, it also occupies a valley lying between the Niagara escarpment and the crystalline old-land on the northeast. As has previously been shown, the Niagara escarpment extends northward from Hamilton into the Indian peninsula between Georgian bay and Lake Huron, and, after passing the Cove island channel, it reappears in the northwestern face of Grand Manitoulin island. At Cabot's head, on the Indian peninsula, the escarpment rises to 324 feet above the surface of the water, while just off the promontory soundings show a depth of 510 feet, thus making the total hight of the escarpment at this point 834 feet. In some places the summit of the escarpment rises to an elevation of 1700 feet above tide, or more than 1100 feet above Georgian bay (Spencer). The depth of the transverse channel connecting Georgian bay and Lake Huron has been found to be 306 feet, which is more than 200 feet less than the depth of the channel of Georgian bay. It is possible however that the soundings do not show the absolute depth of the rock bottom in the channel; for there may be a filling of drift which raised the bottom of the channel above that of the bay.

The valley of Georgian bay is continued northwestward in the channel known as North passage, a narrow body of water lying between the Manitoulin islands and the Canadian old-land. The southward continuation of the lowland is blocked by drift; but a number of borings, between the southern end of Georgian bay and Lake Ontario, east of Toronto, have developed the existence of a buried channel, which connects these two valleys. This channel is considered by Spencer to mark the pathway of his former Laurentian river. It is clear however that this valley is merely the buried connecting part of the inner lowland which extends along the base of the entire Niagara escarpment. This portion of the lowland was originally occupied by two streams flowing, the one northwesterly into the ancient Saginaw, the other southeasterly into the Dundas. The divide between the two may have been in the neighborhood of Lake Simcoe. It is however not at all improbable that the tributary of the Dundas may have, owing to favorable conditions, gained an advantage over that of the Saginaw, and pushed the divide northward. Such a migration of the divide might have resulted in the diversion of the upper waters of the Saginaw by capture, so that they eventually became tributary to the Dundas. This would account for the greater depth of the Georgian bay lowland, which, after the capture of the upper Saginaw waters, could be deepened independently of the notch in the cuesta through which its waters were formerly carried out. This of course is merely suppositional, and the truth can be established only by more detailed study of the ground. It is however what we might expect to happen in the normal adjustment of a coastal plain drainage. This hypothetic relation is illustrated in fig. 6.

The Huron lowland and the Chippewa and Tonawanda valleys. On the yielding strata of the Salina group a second lowland was carved out by subsequent streams, leaving an escarpment capped by the Devonic limestones on the south. This, as we have seen, becomes prominent eastward in the Helderberg range, where the third upper Devonic escarpment unites with it. In the Niagara region it faces the Tonawanda and Chippewa lowlands, which were probably opened out by a subsequent stream tributary to the an-

cient Dundas river. Throughout western Ontario this escarpment is buried by drift, but its presence is indicated by borings, which also prove the continuance of the lowland accompanying it. This escarpment, the inface of the second cuesta, becomes a very prominent feature in Lake Huron, where it is entirely submerged. It is however perfectly traceable from north of Goderich in Canada to the island of Mackinaw. Soundings prove it to have a hight of from 350 to 500 feet or more above the lowland which it faces. This lowland constitutes the deeper portions of Lake Huron, the shallower southwestern area being a part of the upland drowned by the backward setting of the water over the top of the escarpment. The following cross-section (fig. 9) from Point au Sable, north of Saginaw bay, to Cape Hurd, the northern extremity of the Indian peninsula, passes across the highest portion of this escarpment at the 9 fathom ledge and diagonally across the deepest portion of the Huron lowland, where the soundings reach a depth of 750 feet. This apparently marks the location of the preglacial Saginaw river, which probably breached the second cuesta to the south of the 9 fathom ledge, though no channel is indicated by the soundings.

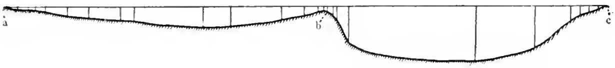


Fig. 9 Section across Lake Huron from Point au Sable, a) across 9 fathom ledge, b) to Cape Hurd, c) (For location of section *see* fig. 6).

We have now traced the development of the topographic features of the Niagara district, and have found this to be in conformity with the laws governing the normal development of drainage systems on an ancient coastal plain. The only abnormal features which need to be considered now are the tilting of the land and the filling of most of the old channels by drift, converting the lowlands into lake basins and reversing the drainage of the unfilled channels. These were the catastrophes which immediately preceded the birth of Niagara and which were directly responsible for its existence. To these and the life history of Niagara, attention will now be invited.

Plate 5

"Rock of Ages," the largest of the fallen limestone fragments at the foot of Luna Falls, on the American side (Copyright by Underwood & Underwood, New York)

Chapter 2

LIFE HISTORY OF NIAGARA FALLS

Glacial period

Two important events immediately preceded the birth of Niagara. The first was the formation of a series of great lowlands and cuestas by stream and atmospheric erosion during a period of time when, according to all indications, the land stood from 2000 to 5000 feet higher than it does now. This was outlined in the preceding chapter. The second event was the accumulation of a great mantle of glacial ice over most of northeastern North America, and the modifications of the previously formed erosion topography, either by the erosive action of the ice or by deposits left on its melting. The time equivalent of the latter event is commonly known as the glacial period of the earth's history, a remote period as time is ordinarily counted, but a very recent one in the chronometry of the geologist. Contemporaneous with this great accumulation of ice was probably the subsidence of the northern part of this region, thus changing the slope of the land surface from a southward to a northward one.

The greatest accumulation of ice during the glacial period appears to have been in the region to the north and northeast of the great lakes, or in general over the area of the Laurentian old-land. The immediate causes which brought about such accumulation, were the extensive refrigeration of the climate and the increased precipitation of moisture, so that a greater amount of snow fell during the winter seasons than could be removed by melting during the succeeding summers. The partial melting and refreezing of the snow, which continued over a long period of time, eventually resulted in producing glacier ice, after the manner of the formation of glaciers at the present time.

The thickness of the great Laurentian glacier, which eventually covered all the land of this region, including even the highest mountains, must be estimated at thousands of feet in its central part with a progressive diminution of thickness toward the margin. The ice

of glaciers, as is well known, has a certain amount of plasticity and will flow under the pressure of its own weight, somewhat after the manner of a mass of pitch. The flow of the great Laurentian glacier was outward in all directions from the center of accumulation, local topographic features exerting a deflecting influence only in the more attenuated marginal portions. In its basal portions, the ice was well supplied with rock debris, from the finest rock flour and clay to boulders often of very great size. This material was derived from the surface over which the ice flowed, and it measured in part the amount of erosive work which the ice had accomplished. The rock fragments frozen into the bottom of the moving ice mass, served as efficient tools for grooving and scratching the bedrock over which the ice flowed, while at the same time the finer material smoothed and polished the rock surfaces. The direction of the grooves and striae on the rock surfaces in general indicate the direction of the movement of the ice which produced them, but this may not always represent the direction of general ice movement for the region, since, at the time of making the striae, the ice may have been thin enough to be influenced by the local topographic features of the region. In the Niagara district the striae have a direction extending about 30° west of south (Gilbert) which direction, being inharmonious with the trend of the lowlands, indicates that these striae were formed by the general movement of the ice, rather than by local movements, controlled by topography.[1]

While the surface rocks of this region were everywhere scratched and polished by the ice, these markings are only exhibited where the protecting mantle of loose surface material or drift has been recently removed. For where the polished rock surfaces are exposed for any considerable period of time, weathering usually obliterates these superficial markings. The best place in which the striae of the region about Niagara river may be studied is near the quarries on the edge of the escarpment, a mile or more west of Brock's monument, where the ledges are progressively uncovered previous to quarrying.

[1] For an account of the glacial sculpture in this region, *see* Gilbert. Bul. geol. soc. Am. 1899. 10:121.

Throughout the greater part of the district, the polished rock surfaces are covered by a coating of drift of very varying character and thickness. This was the ground moraine or till of the Laurentian glacier, and represents the rock debris which was frozen into the bottom of the ice, and carried along in its motion, till liberated by the melting of the ice. This ground moraine, either in its original heterogeneous character or modified by the agency of running water, filled most of the old river gorges through which the drainage of preglacial times found its exit. Some of the shallower lowlands, like that of the Tonawanda, were also filled with drift, while the more profound ones, like the Erie and Ontario lowlands, received only a partial drift filling.

The partial obliteration of the old drainage channels, which was thus brought about, together with a depression of the land on the northeast to a depth below that at which it now stands, converted the unfilled lowlands into lake basins, apparently reversed the drainage of many streams, forcing them to cut gorges where their old channels were drift-filled, and finally became the immediate factors in the formation of Niagara.

Lacustrine period[1]

During the slow melting of the glaciers in the Laurentian region, and the resultant northward retreat of the front of the ice, large bodies of water, of varying depth and extent, were held in front of the ice sheet, which formed a dam across the northeastern part of the lowland country, the general slope of which was now toward the ice instead of away from it. The elevations of these glacial lakes were determined by the lowest uncovered passes in the margins of the lake basins across which the discharge took place, and, as during the continued melting of the ice dam, lower passes were progressively uncovered, the outlets were successively transferred to them and the levels of the lakes sank correspondingly.

[1] For a detailed account of the successive stages in the development of the great lakes, the shore lines, outlets and extent of each, the reader is referred to the papers by Gilbert, Spencer, Taylor, Leverett, Fairchild and others, cited in the appendix.

Though of a temporary nature, these bodies of water endured sufficiently long to permit the formation of well marked beaches with their accompaniment of bars, sand-spits and other wave-formed features. These have been carefully studied and mapped by a number of observers, and the general extent and outline of these lakes is today pretty accurately determined.

The largest of these glacial lakes, though not the first to come into existence, was glacial Lake Warren. "At its maximum extent Lake Warren covered the south half of Lake Huron, including Saginaw bay, the whole of Lake Erie and the low ground between it and Lake Huron; extended eastward to within twenty or thirty miles of Syracuse, N. Y. and probably covered some of the western end of Lake Ontario."[1] The retaining ice wall on the east extended in a northwesterly direction, across western New York, Lake Ontario and the northeastern end of Lake Huron. This position of the ice front is in part inferred from the existence of moraines of sand and gravel along a portion of that line. The total area of this ancient lake has been variously estimated as including from one hundred thousand to two hundred thousand square miles of surface but this estimate is based on the assumption that the lake occupied the greater part of the area of the present upper Great lakes, with the intervening land, a supposition which Taylor holds to be incorrect. The area of Lake Warren was probably less than 50,000 square miles, or approximately half that of the state of Kansas. The extent and level of this lake was not constant, there being many oscillations, due chiefly to warpings of the land surface. These oscillations are recorded in the various beaches which have remained to the present time. The chief outlet of Lake Warren was by way of the Grand river valley into the valley of Lake Michigan, the southern end of which was then much expanded and occupied by the waters of "Lake Chicago." The outflow of this lake was to the Mississippi by way of the Illinois river, across the divide near where Chicago now stands, thus temporarily reestablishing the southward drainage of this region.

[1] Taylor. A short history of the Great lakes, p. 101.

As the ice front continued to melt away, retreating northeastward, drainage at a lower level was permitted along the ice front to the Hudson valley, and the sea. As a result, the water level sank, the Chicago outlet was abandoned, and Lake Warren became much contracted and in part cut up and merged into new bodies of water. The largest of these was glacial Lake Algonquin, which occupied the basins of the three upper Great lakes, and seems to have been for a long time independent of Lake Erie, which after the division of Lake Warren was for a time much smaller than it now is. (Fig. 11 and 13)

The critical period in the development of the lakes, with reference to the birth of Niagara, was the uncovering of the divide at Rome (N. Y.) and the consequent diversion of the drainage into the present Mohawk valley. This brought with it a subsidence of the waters north of the Niagara escarpment to the level of this outlet, which was considerably below that to which the other lakes could subside, owing to the rocky barriers which kept them at greater altitudes. As a result Niagara river came into existence, though at first it was only a connecting strait between Lake Erie and the subsiding predecessor of Lake Ontario. The overflow from Lake Erie occurred at the present site of Blackrock, because there happened to be the lowest point in the margin of the lake. It is not improbable that a small preglacial stream had predetermined this point, either flowing southward into the river occupying the Erie basin, or northward as an obsequent stream into the Tonawanda. The course of the river below Blackrock was determined by the directions of steepest descent of the land surface, which was probably predetermined to some extent by preglacial streams. As soon, however, as the level of the waters of the Ontario valley sank below the edge of the Niagara escarpment at Lewiston, a fall came into existence, which daily increased in hight as the level of the northern lake was lowered. From that time to the present, Niagara has worked at its task of gorge-cutting, the present length of the gorge, from Lewiston to the falls, marking the amount of work accomplished.

When the waters north of the escarpment had subsided to the level of the outlet at Rome, a long period of stability ensued, during which extensive and well marked beaches were formed by the waves. This comparatively long-lived body of water has been named Lake Iroquois, and its outline is shown in the accompanying map (fig. 10) reproduced from Gilbert's *History of the Niagara river.* The Iroquois shore lines in this region may be seen in the ridge road which extends eastward from Lewiston, and westward from Queenston, closely skirting the foot of the escarpment.

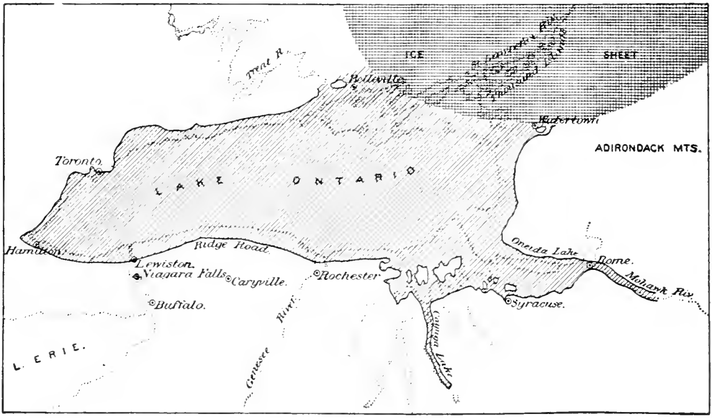


Fig. 10 Map of Lake Iroquois; the modern hydrography shown in dotted lines. (After Gilbert)

A fine section of this old beach is seen just behind the railroad station at Lewiston. Here the layers of sand and gravel slope steeply toward the southeast, and many of them are irregular and wedge-shaped. Some of the beds, a foot or more in thickness, consist entirely of rounded pebbles, with little or no sand between, forming a porous mass of "loose gravel". The prevailing rock of the pebbles is the Medina sandstone, derived from the neighborhood, and the pebbles are always well waterworn, and commonly of the flattened type characteristic of thin bedded rocks. Mingled with the beds of coarse material are layers of fine sand, the structure of which is well brought out by exposure to wind and weather. Not

infrequently masses of sand and pebbles are cemented into a conglomerate by calcite or other cementing agents.

The terminal portion of the beach at the Lewiston station is rather exceptional. It has here the character of a sand spit, extending toward the Niagara river. Between this spit and the escarpment there is a low area of irregular outline, something over half a mile in width along the river and extending perhaps three fourths of a mile eastward from it. This area is bounded by steep erosion cliffs of unconsolidated material, and is from 30 to 50 or more feet lower than the level of the ridge road. The suggestion presents itself, that these features may be due to the current of the Niagara at its *embouchure* into Lake Iroquois, at a time when the falls were probably not far distant. (*See* plate 3 and map)

There is evidence that the level of Lake Ontario at one time stood much lower than it does at present; for the bottom of the lower Niagara, from Lewiston to the lake, is from 100 to 200 feet below

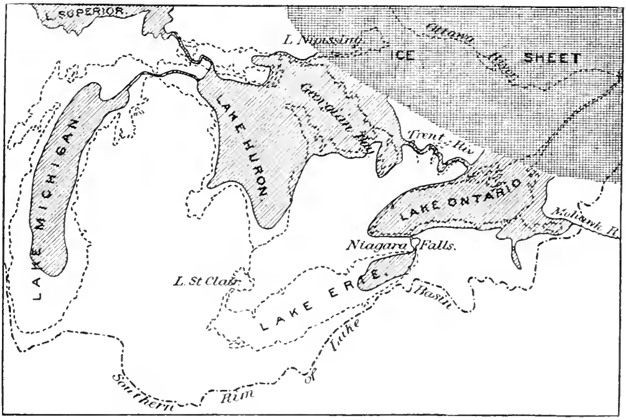


Fig. 11 Gilbert's map of the Great lakes at the time of the Trent river outlet. Modern hydrography dotted.

the present water level. In fact, the old beaches about Lake Ontario indicate a number of oscillations of level, similar to those recorded in the other glacial lakes, and due chiefly to crust warpings.

Lakes Algonquin and Iroquois were probably contemporaneous, and it is believed that for a time the former discharged its waters to the latter by way of Balsam lake and along the course of the Trent river. This discharge by way of the Algonquin river, as this old outlet of Lake Algonquin has been called, robbed the Niagara river of seven eighths of its water supply, which up to then had reached it by the present course through the Detroit river. As a result, the volume and erosive power of the river were for a time enormously diminished. (Fig. 11 and 13)

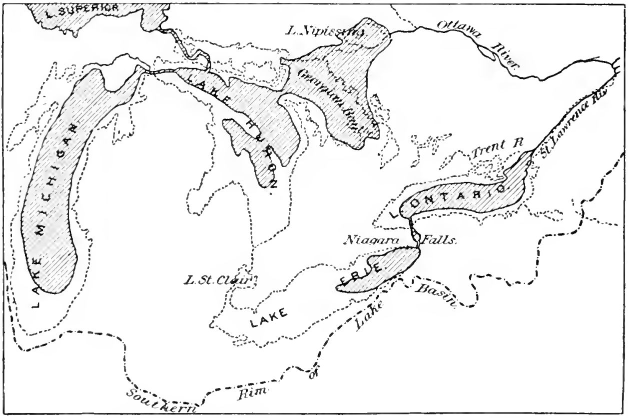


Fig. 12 Gilbert's map of the Great lakes at the time of the Nipissing outlet. Modern hydrography dotted.

During the farther retreat of the ice front, a still lower pass was opened by way of Lake Nipissing and the Mattawa river into the Ottawa. By the time this outlet was opened, the ice had also disappeared from the St Lawrence valley, and the outlet of the waters of the great lakes was transferred from the Rome channel to the one at the Thousand islands, Lake Iroquois at the same time subsiding to Lake Ontario. (Fig. 12 and 14)

The successor of Lake Algonquin, after the change from the Balsam lake to the Nipissing lake outlet, has been named by Taylor, Nipissing great lakes, while the river which carried its discharge to the Ottawa was called by him the Nipissing-Mattawa (fig. 14).

With the gradual melting away of the great ice sheet, the land on the northeast began to recover from its last great depression,

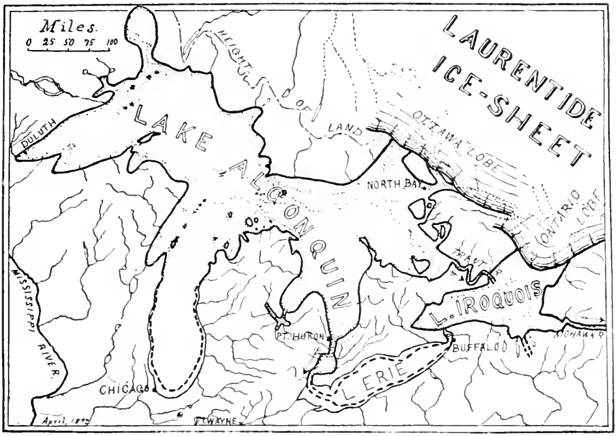


Fig. 13 Taylor's map of Lakes Algonquin and Iroquois.

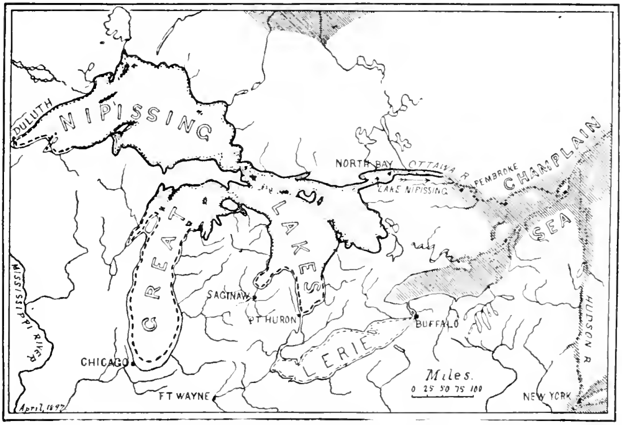


Fig. 14 Taylor's map of Nipissing great lakes and the Champlain submergence.

and, though there had been many oscillations, the balance of change was toward a slow but steady elevation of the Laurentian region. As a consequence the beaches of the old glacial lakes, which of

course had a uniform elevation while forming, are no longer of uniform hight above sealevel, but rise progressively toward the northeast. This slow rising of the land caused a gradual canting of the basins, which brought with it a relative fall of the waters along the northeastern shores and a corresponding relative rise of the waters along the southwestern shores. Such a progressive change eventually carried the Nipissing and Balsam lake outlets above the level of the outlet at Port Huron, and the present drainage was reestablished. As the canting affected the Erie basin as well as the others, it caused a progressive elongation of that lake toward the southwest, thus finally giving it its present size and shape. This same canting also resulted in the farther separation of the upper lakes into their present divisions.

While this general outline of the lake history is held by many geologists, others, notably Upham, combat it strongly. Mr Upham holds that the elevation of the land in the northeast had progressed to such an extent by the time the ice had uncovered the northern outlets of Lakes Algonquin and Nipissing, that these passes had been raised above the altitude of the outlet at Port Huron, and that hence these passes never, or but for a brief period of time, served as outlets for the waters of the upper lakes. If this is the case, Niagara always carried the drainage of the upper great lakes as well as Lake Erie, and its volume was approximately uniform throughout its history. The strong erosion features, however, which are found in the Mattawa valley indicate that a large stream discharged here for a considerable period of time; and, if such was the case, it is highly probable that the present Port Huron outlet was not then utilized, and that consequently the Niagara was robbed of the discharge of the upper lake area. The influence on the erosion of the gorge by such a withdrawal of the water must have been a pronounced one, and we shall see later that certain portions of the gorge may well be explained by this hypothesis. During the time of the overflow of the upper waters by way of the Nipissing-Mattawa river it is not improbable that, as held by Taylor and others, the sea had access to the St Lawrence and Ontario basins and possibly to the basins of the upper lakes. This would account for the occurrence of marine types of organisms in the deeper portions of some of the present

great lakes as well as for the maritime species of plants found in the lake district. It must however be borne in mind that this marine invasion was not till after the time of Lake Iroquois, for fresh-water fossils have been found in the beaches of this lake.

The tilting of the land, which is recorded in the deformed beaches, has not yet ceased, as recent investigations in the lake regions clearly prove. Mr Gilbert has made an extended study of this problem; and he has been led to the assumption "that the whole lake region is being lifted on one side or depressed on the other, so that its plane is bodily canted toward the southsouthwest, and that the rate of change is such that the two ends of a line 100 miles long and lying in a southsouthwest direction are relatively displaced .4 of a foot in 100 years". From this it follows that "the waters of each lake are gradually rising on the southern and western shores or falling on the northern or eastern shores, or both". This implies of course a drowning of the lower courses of all streams entering these lakes from the southwest and an extension of those entering from the northeast. Assuming that the rate and character of change will be constant in the future, the following interesting results have been predicted by Mr Gilbert. The waters of Lake Michigan at Chicago are rising at the rate of 9 or 10 inches a century; and "eventually, unless a dam is erected to prevent, Lake Michigan will again overflow to the Illinois river, its discharge occupying the channel carved by the outlet of a Pleistocene glacial lake. . . Evidently the first water to overflow will be that of some high stage of the lake and the discharge may at first be intermittent. Such high water discharge will occur in five hundred or six hundred years. For a mean lake stage such a discharge will begin in about one thousand years, and after one thousand five hundred years there will be no interruption. In about two thousand years the Illinois river and the Niagara will carry equal portions of the surplus water of the great lakes. In two thousand five hundred years the discharge of the Niagara will be intermittent, falling at low stages of the lake, and in three thousand five hundred years there will be no Niagara. The basin of Lake Erie will then be tributary to Lake Huron, the current being reversed in the Detroit and St Clair channels."[1]

[1]Gilbert, G. K. Recent earth movements in the great lake region. 18th an. rep't U. S. geol. sur. 1896–97. pt 2.

Fluvial period

Niagara falls came into existence when the waters of Lake Iroquois, the predecessor of Lake Ontario, fell beneath the level of the escarpment at Lewiston. At first it was only a small cataract, but day by day, as the lake subsided, it gained in hight and consequently in force of fall, as well as efficiency in cutting its channel. That the entire gorge from Lewiston to the present falls is the product of river erosion is scarcely questioned by any one today, but there are excellent reasons which lead some to believe that this cutting was not wholly the work of the Niagara. When the falls were at Lewiston, the Niagara was a placid stream from Lake Erie to near the falls, much as it is today from Buffalo to the northern end of Grand island. Its banks consisted chiefly of glacial till, into which terraces were cut by the stream, most of which are visible at the present day. The lower ones are well marked in Prospect park, though there they have been grassed over and modified to a considerable extent. From Niagara falls to the railroad bridges at Suspension Bridge, on the New York side of the river, the old bank runs parallel to the edge of the gorge and at a short distance inland from this. From Suspension Bridge to the whirlpool it makes a curve somewhat more crescentic than that of the margin of the gorge, and a similar curve from the whirlpool to Bloody run at the Devil's hole. On the Canadian side these old river banks can be traced from above the falls almost to Brock's monument, and in some cases two or three successive terraces are recognizable. In Queen Victoria park they constitute the steep slope which bounds the park on the west, and parts of which are still actively eroded. Less than a mile below the carriage bridge, the old banks approach close to the modern one and continue, almost coincident with it, to the railway bridges at Clifton. From here to the whirlpool the old river margin has a nearly straight course, while the modern one is curved, and a similar relation holds below the whirlpool, though here, from the great curvature of the modern channel, the old banks are in places nearly a mile distant.[1] (Plate 6)

[1] These old river banks are indicated on the geologic map by dotted lines; the localities where shells have been found are shown by crosses.

Plate 6

Old banks of the Niagara on the New York side, below the railroad bridges (U. S. geological survey)

Within the old channel thus outlined, which was much broader than the modern channel below the falls, accumulations of stratified sands and gravels were formed in the more protected places, much as such deposits are formed in streams today, where sands are swept into protected areas. With these sands and gravels were swept together the shells of those mollusks which lived in the river water, and many of which were of the species now found living in the upper Niagara.[1] Most of the shells thus swept together were probably of dead individuals, though living ones may also have been carried into these growing deposits. Many excavations have been made in these ancient deposits, fragments of which are preserved in various places between the former and present banks of the river. The most notable of these and the one longest known is on Goat island, perhaps a quarter of a mile inland from the edge of the cliff, at the Biddle stairway. In the section opened here, most of the material is seen to be coarse and rudely stratified. The pebbles are subangular, often quite angular, while some appear to be scarcely worn at all. Blocks a foot or more in diameter are not infrequent, the material being generally limestone from adjoining ledges, though fragments of sandstone and of crystalline rocks are not uncommon. Occasionally a lens of fine sand occurs which shows cross-bedding structure, the laminae pointing in a northwesterly direction. The shells are found on the cross-bedding planes, conforming with them, and indicating that they were spread there by the current which moved the sand grains. Among the coarse material the shells are mixed indiscriminately. In many cases the gravels are of the loose type, with scarcely any sand between them, indicating deposition by a powerful current. Along these zones air and water have most readily penetrated, and a deposition of iron oxid has been formed which stains both pebbles and shells. The shells are generally very fragile, and commonly show signs of wear. Gastropods are most abundant in the Goat island gravels.

In Prospect park several excavations formerly exposed these gravels. The deposit here consists of sand and gravel with the pebbles moderately rounded, though occasionally subangular, and

[1]For descriptions and illustrations of these shells, *see* chapter 5.

varying in diameter up to 6 inches or a foot. The stratification is rude, and shells are abundant. These are mostly fresh-water mussels (Unio, Alasmodonta, etc.) and the valves are generally found in conjunction, a fact which may indicate that these shells lived here. Small gastropod and pelecypod shells are plentifully mingled with the pebbles and sands. Below this are coarser deposits where boulders up to several feet in diameter occur, and below this occurs a bluish clay. In all of these beds shells have been sparingly found.

Several excavations have been made in Queen Victoria park, and here shells are common. The Unionidae appear to be most abundant, though small gastropods are not uncommon. All appear to have been more or less waterworn. The mussel shells are generally decayed, owing no doubt to percolating waters. Below Clifton, the lower of two terraces is of a somewhat sandy character, though many boulders occur in it. Shells of unios occur sparingly in these deposits, and a few small gastropods were found in the lowest terrace. Farther north several excavations in the lower terraces of the old river show loose gravels alternating with a sort of till, a few Goniobasis and other gastropod shells being found here. In some cases the gravels have become cemented into a conglomerate by a deposit of calcite between them, often of considerable thickness. Boulders of similarly cemented gravels are found in the gorge below, at the whirlpool.

It will thus be seen that, throughout the greater part of the young Niagara, deposition was going on as well as erosion. The amount of erosion of the river bed was probably very slight, that of the banks being much more pronounced. The chief part in the cutting of the gorge was enacted by the cataract, which cut *backward* from Lewiston, the amount of *downward* cutting by the river being insignificant. The manner in which the cataract performed its work of cutting may today be observed in both the American and Canadian falls, as well as in waterfalls of other streams falling over strata, the arrangement of which is similar to that obtaining at Niagara. The essentials are a resistant stratum overlying a weak one, the latter being constantly

Plate 7

Cliff on the Canadian side of the gorge, showing the receding base. The giant icicle marks the edge of the overhanging ledge (Copyright by Underwood & Underwood, New York)

worn away by the spray generated by the falling water, thus undermining the resistant layer. Such undermining may be seen in the Cave of the Winds. In course of time this undermining progresses so far that the projecting portion of the capping stratum breaks down for want of support, and the crest line of the fall becomes abruptly altered. The fallen fragments accumulate at the foot of the fall, where they will remain if the force of the water is unable to move them, as illustrated by the rock masses lying at the foot of the American fall. If, however, the force of the falling water is great as at the Horseshoe falls, these blocks will be moved about, perhaps even spun about, and so made to dig a deep channel below the falls. In the soft rocks which lie at the foot of the Horseshoe falls a channel probably not less than 200 feet in depth has been dug in this manner. (Fig. 15)

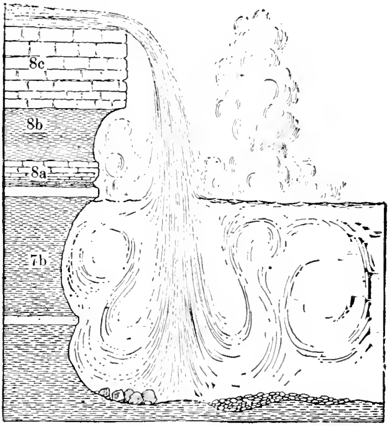


Fig. 15 Sectional view of the Horseshoe falls showing arrangement of strata, and depth of water below falls. (After Gilbert) The numbering of beds corresponds with that of table.

When we consider the Niagara gorge in detail we find it to be much more complex than would at first appear. The first abnormal feature which presents itself in a map view of the entire gorge is the bi-crescentic character of its course, with the rectangular turn at the whirlpool, a course very different from that which we are accustomed to find in large rivers whose direction of flow

has been uninfluenced by preexisting relief features. (Fig. 16) Another feature of importance is the varying width of different parts of the gorge, and the corresponding increase in velocity of current in the narrower parts. The depth of the channel also varies in different portions of the gorge, being in general greater in the wider and less in the narrower parts. (Fig. 18)

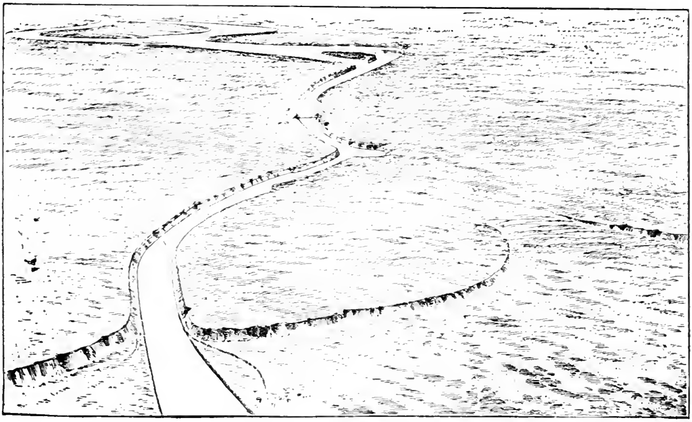


Fig. 16 Birdseye view of Niagara gorge showing the course of the river; the falls, the railroad bridges, whirlpool, location of Fosters flats, escarpment at Queenston and flaring mouth of old St Davids gorge. (After Gilbert)

The first mile and three fourths of the gorge, or that portion marking the retreat from the escarpment to the Devil's hole, extends nearly due south, and is fairly uniform in width, comparatively narrow, and with a current of great velocity. The narrowness of this stretch, when compared with the channel made by the present cataract from the railroad bridges southward, seems to indicate a smaller volume of water during its formation than that now passing over the falls. An alternative hypothesis accounts for the narrowness of this section of the gorge by assuming it to be a preglacial drift-filled channel, made by an obsequent stream flowing northward to the Ontario lowland, similar to that which made the old St Davids channel, but reexcavated by the Niagara. It is highly probable that there was at least a shallow channel which served as

a guide to the young Niagara. The southward continuation of this channel beyond the Devil's hole, is found in the valley of Bloody run, a shallow but distinct depression now followed in part by the Lewiston branch of the New York Central railroad and evidently of preglacial origin, as its floor is covered with till.

Next above this lowest section of the gorge is one, in general much broader, and extending in a southwest direction from the Devil's hole to the whirlpool, a distance of a little less than two miles. This section is contracted near its middle by the projection from the Canadian bank, known as Fosters flats, or Niagara glen. The river is here scarcely 300 feet wide, though the tops of the banks are in places over 1700 feet apart. Above Fosters flats and almost as far as the whirlpool, the river is very calm, and apparently deep, while at the point of contraction at the southern end of Fosters flats, the waters suddenly become tumultuous and rush through the narrow channel with great velocity. This sudden change has been attributed to a sudden decrease in depth of the river at this point, but it is evident that, even if the channel had the same depth as above, the sudden contraction would produce a similar effect, for the waters, spread out over a broad and deep channel, on being suddenly forced to pass through a narrow one, would from mere crowding into a smaller space assume a violent aspect.

Niagara glen, or Foster's flats

PLATE 8

This is one of the most interesting places along the whole Niagara river, though generally little visited by tourists. From the Canadian side a platform of limestone projects, whose surface is a little below that of the general level of the upland plain, from which it is separated by a steep bluff. The platform is known as Wintergreen flat, and, though sparingly wooded, is very deficient in soil. The bluff which bounds it on the west is a part of the old river bank. On the remaining sides this platform is limited by abruptly descending cliffs, at the base of which are extensive talus slopes descending to a lowland of considerable extent. This lowland, which is known as Fosters flats, has its surface well strewn

with huge boulders of limestone. The cliff which limits Wintergreen flat on the northern or downstream side is the highest and most precipitous, and from its base a well marked, dry channel leads northward for a third of a mile to the river's edge. This channel is separated from the present river channel on the right by a ridge which appears to consist of huge limestone blocks, though its base is probably formed by undisturbed remnants of the lower strata of the region. The floor of this old channel is strewn with huge limestone boulders, such as are found at the foot of the American falls today, and its left bank is the precipitous west wall of the Niagara gorge. (Fig. 17)

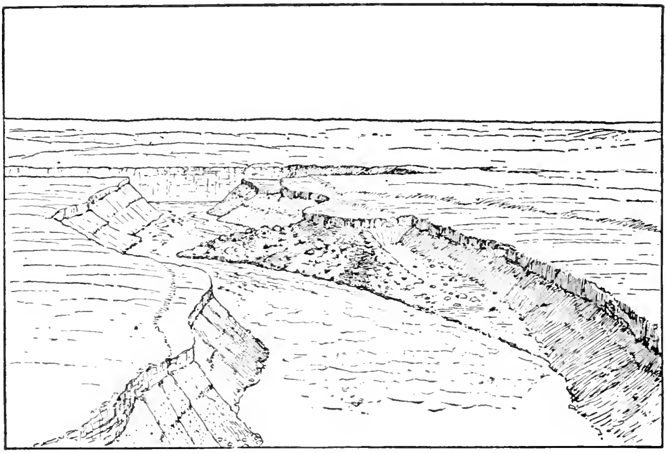


Fig. 17 View of Niagara glen or Foster's flats, looking south. Forests omitted. (After Gilbert)

These various features have been well explained by Mr Gilbert,[1] who holds that a narrow island comparable to Goat island, divided the fall in two, when it had receded to the northern end of Fosters flats. The foundations of this island, which has since crumbled away, are seen in the ridge which divides the old dry channel on the left from the main bed of the river. The eastern or American fall at that time was the larger of the two, and it receded more

[1] Nat. geog. monographs. Niagara falls and their history.

Plate 8

Wintergreen Flat looking south; showing the platform which was formerly the river-bed, and the cliff in the center which was once the site of a fall.

rapidly. "When the Canadian fall reached the head of the island, the American had just passed it, and part of the sheet of water on Wintergreen flat was drained eastward into the gorge opened by the American fall. The Canadian fall, through the loss of this water, became less active, and soon fell out of the race."[1] By the final retreat of the American fall beyond the southern end of Wintergreen flat, the latter was left as a dry platform with precipitous sides, over which once poured a portion of Niagara's torrent.

While the occurrence of an island in the position pointed out by Gilbert was undoubtedly the immediate cause of the division of the falls, the more fundamental cause, and the one to which the island itself owed its existence, is to be sought elsewhere. From an inspection of the map the suggestion presents itself that there may be a vital connection between the abandoned falls at Fosters flats and the great bend of the river at the whirlpool. When a great river runs for a mile or more in a straight line, as the Niagara does above the whirlpool, and then abruptly turns to the right, the current is deflected by this sudden change in direction to the right bank of the river below the bend, which it continues to hug till again deflected. It is thus that the greatest amount of water will be carried along the right bank of the river, causing a deeper channeling there. When Niagara falls had receded to the present northern end of Foster's flats, the greatest amount of water was carried over its right side. The resulting deepening of the channel on the right, and the consequent drawing off of the water toward that side, was the cause of the appearance of the island (if such existed, as seems probable from the remaining foundation) above the water and the consequent division of the falls. A precisely analogous feature occurs in the lower falls of the Genesee river below Portage. Here, however, no island was formed, though in other respects the two cases are nearly alike. In the Genesee the change has occurred in comparatively recent times, and records of earlier conditions have been preserved. An abrupt bend of the river to the right, deflected the current to the right bank below the bend, and thus caused the deepening of the river bed on that side, as well as the more rapid

[1]Gilbert. Nat. geog. monographs. Niagara falls and their history.

recession of the right hand portion of the falls. In the course of a comparatively short time the channel became so deep on the right, and the falls receded so fast on that side, that all the water was drawn off from the larger portion of the river bed on the left, which today remains as a triangular platform comparable to Wintergreen flat, with steep sides, and several hundred feet wide, at its downstream end. The river now flows in a channel, in places less than 10 feet wide, and 100 feet below the level of the platform which was its bed less than 100 years ago. The present lower fall, having mostly receded beyond the upstream end of the platform, again extends across the entire bed of the river. The water in the river has not, as far as known, changed in average volume, though above and below the narrow part the gorge is many times as wide. All the water which passes in a thin sheet over a broad fall above the narrow gorge is forced to pass through this contracted portion, and presents a rushing current, though the bed is deeper here than where the gorge is broader. The time required for the recession of the fall over the space of the 2000 feet of narrow gorge, must have been much shorter than that required for the recession through a similar length in the broader portion of the gorge, for the concentration of the waters here enabled it to do much more effective work.

Judging by analogy, we may assume that the narrow channel opposite Foster's flats was cut by a stream of the full power of the present Niagara, but whose main mass of waters was carried over the right side of the fall on account of the bend in the stream above. The present Horseshoe falls is cutting a much narrower gorge than that to the north of it, owing to its peculiar position at the angle of a second great bend. (Fig. 19) From the fact that the cutting was most profound on the eastern or right bank of the river at Foster's flats, this bank has received the precipitous character which it has retained to the present day.

An interesting fact bearing on the interpretation of the history of Foster's flats, is the occurrence in the sands among the huge boulders near the foot of the ancient falls, of shells of the small fresh-water gastropod, Pomatiopsis lapidaria Say,[1]

[1] *See* chapter 5.

which is found living in the Niagara river today, but only on the rocks and boulders lying in the constant spray of the modern cataract.

After passing Foster's flats, the scene of greatest erosive activity seems to have been transferred to the left bank of the river. This is indicated by the verticality of this side of the gorge south of Foster's flats, which suggests active erosion, while the lowland known as Ongiara park opposite to this on the New York side of the river, with its enormous boulders scattered about, recalls the dry channel on Fosters flats or the foot of the present American fall, and suggests an amount of water insufficient to remove them. This may be accounted for by assuming that the nearness of the fall had

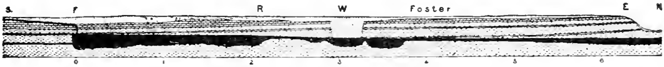


Fig 18 Longitudinal section of the Niagara gorge from the falls F to Queenston hights E, showing strata of west bank and depth of channel. (After Gilbert) R railway bridges. W whirlpool. Foster = Foster's flats. Figures indicate miles.

given the river itself greater momentum above the fall, and that hence it dug deeper into the old drift-filled valley of the St Davids at the whirlpool. As a result, the deflection of the current to the right bank became more abrupt, striking the New York bank immediately south of where Ongiara park now is, and, being again deflected toward the Canadian side, it reached this just at the southern end of Foster's flats, thenceforth for a time causing the most active erosion on that side. The washing out of the drift from the old St David's channel furnished the river with tools with which it was able to cut down into its bed, so that in this portion erosion was probably both by backward cutting of the falls and downward cutting of the river above the falls.

We have so far considered the falls as of simple type, but it is by no means certain that such was the case. If we judged from analogy with other streams which have cut gorges in the same strata as those found at Niagara, we should suppose that, as in the case of these streams, a separate fall was caused at Niagara by each resistant layer. Thus in the lower Genesee river, at Rochester, one fall is caused by the upper hard bed of the Medina formation, an-

other by the limestone of the Clinton group, and a third by the Lockport limestone. In the Niagara river we might suppose that at least three, and possibly four, falls had existed at one time. The lowest of these would have been over a hard bed of sandstone, about 25 feet thick, and about 100 feet below the top of the Medina group. Another might have been caused by the hard capping stratum of Medina sandstone, 10 feet thick. A third over the 30 feet of Clinton limestone; while a fourth would have been formed over the Lockport limestone. The second and third would perhaps unite in one, as the shale bed between the two resistant layers is only 6 feet thick. It may however be objected that in a great cataract the force of the falling water is such as to cause uniform recession of all the layers, and that hence only one great fall existed.

The whirlpool

PLATE 9

Perhaps the most remarkable part of the entire gorge is its great swollen elbow, the whirlpool. Here the current rushing in from the southeast with great velocity, circles around the basin and finally escapes, by passing under the incoming current, through the comparatively narrow outlet, in a northeasterly direction. The waters in the whirlpool have probably a depth of 150 or 200 feet, but both the outlet and the inlet are shallow, for here ledges of the hard quartzose bed of the Medina formation project into the river, extending in the latter case probably across the channel. An examination of the walls of the whirlpool basin shows that rock is absent on its northwestern side, the wall here being formed of unconsolidated material or drift. This is best seen on descending to the edge of the whirlpool on the Canadian side, through the ravine of Bowmans creek. It will be observed that the Niagara has here exposed a cross-section of the ancient drift-filled channel which extends southeastward from St Davids. This channel appears to have been that of a preglacial stream of the obsequent type,[1] which was tributary to the streams of the Ontario lowland. Some geologists however, notably Mr Taylor, believe that this old channel may have

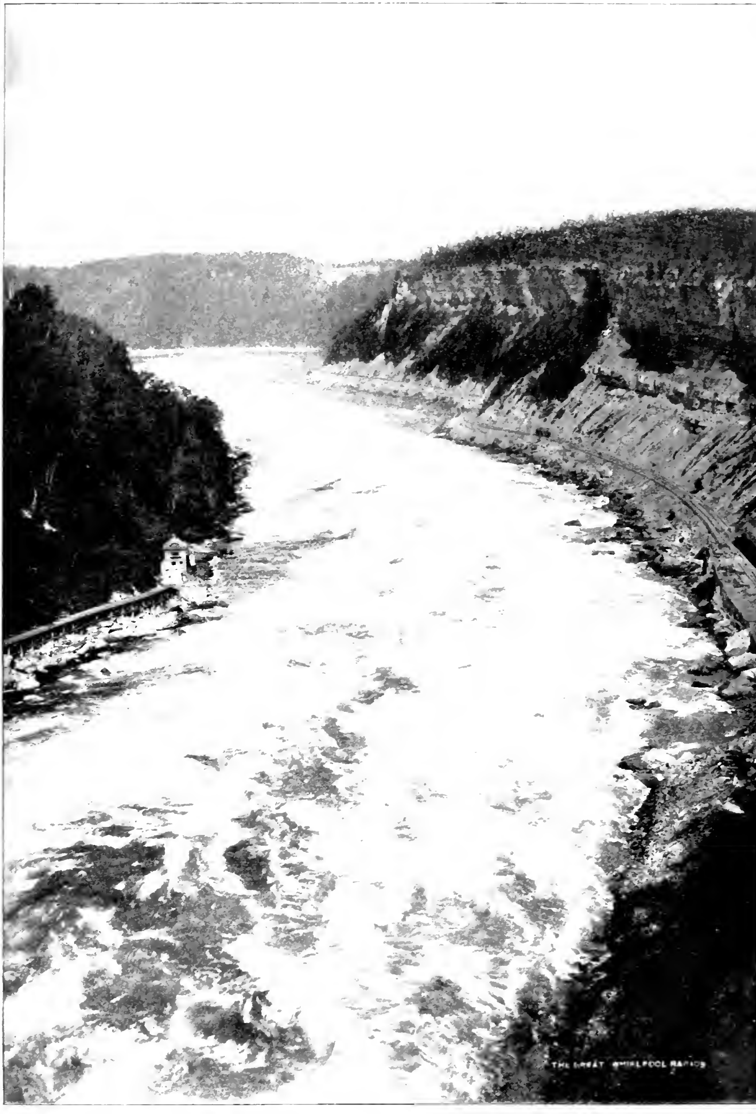
[1] *See* chapter 1.

The Whirlpool from the Canadian side. The ledges projecting at the water's edge, at the outlet, are the gray band in the Medina.

been formed by a river and cataract similar to the Niagara of today, during interglacial time. That this old channel was once occupied by ice is shown by the glacial scratches on the limestone ledges exposed in the western wall of the old gorge, where this has been cleared of drift by Bowmans creek, and it is apparent that the filling in by drift must have occurred after the ice occupation. An inspection of the map will show that a part of the present Niagara gorge, that containing the whirlpool rapids, is in direct continuation of the old St Davids channel, and that, a little above the railroad bridges, the Niagara makes a pronounced bend, which brings it in conformity with the direction of this channel. This suggests that there was at least a shallow depression, the insignificant southeastward continuation of the St Davids channel, which guided the waters of the Niagara in this direction. Here a question of great importance in the history of the Niagara presents itself. Did the ancient St Davids gorge end where is now the south side of the whirlpool, with only a shallow surface channel extending beyond this point, or was the gorge of the whirlpool rapids a part of the old St Davids channel, which was merely cleared by the Niagara of the drift that filled it? The latter condition was assumed to be the true one by Dr Julius Pohlman of Buffalo, a pioneer in the study of the Niagara gorge and the first to recognize the complexity of the channel and attempt to account for its varying character. The theory is still held by many geologists. On the other hand, Taylor and others think it more likely that the ancient gorge stopped where is now the inlet to the whirlpool, and that the gorge above it is the product of post-glacial erosion. If this view be accepted, the narrowness and shallowness of the gorge of the whirlpool rapids must be accounted for by some change in the volume of water during its formation. Taylor, who has studied this problem, has come to the conclusion that, during the time that the gorge of the whirlpool rapids was being excavated, the upper great lakes (then united into Lake Nipissing) discharged by way of the Nipissing-Mattawa river as already outlined, and that therefore Niagara drained only the shallow Lake Erie, the amount of water in the river being only one eighth its present volume. It is easy to see that such a reduc-

tion in volume would lead to a great decrease in cutting power, and that the resultant gorge would hence be much narrower and shallower than the one cut when the water supply was as large as at present. The Nipissing-Mattawa outlet was finally closed, as we have seen, by the elevation of the land on the north, and the upper lakes assumed their modern outlet by way of Port Huron. As a result the water supply of Niagara was greatly increased, and the broad and deep gorge, which extends from south of the railway bridges to the present falls, was cut by a cataract of the size of the present Horseshoe falls, which in addition carried the water now passing over the American falls. This correlation between change in drainage of the upper lakes and change in size of the gorge of Niagara is certainly very suggestive, and seems admirably to account for many features observed in the gorge. For example, it explains satisfactorily the sudden widening of the gorge just before reaching the whirlpool, forming what Taylor has called the Eddy basin, from the strong eddy which characterizes this portion of the river. This wider part of the gorge Taylor believes was formed by the same large-volume river which cut out the broad channel north of the whirlpool, and he farther thinks, that the sudden change from this broad channel to the narrow one of the whirlpool rapids marks the reduction in volume of water on the opening of the Nipissing-Mattawa channel, which had hitherto been blocked by the remnant of the Laurentian glacier. There are however several features which must be satisfactorily explained before this theory (which Upham rejects on grounds already stated) can be accepted. It is highly probable that the gorge of St Davids was worn back beyond the whirlpool. From the great depth of the whirlpool basin, and the presence of the quartzose sandstone bed at the inlet to it, it seems probable that a fall existed here in the ancient stream which carved the St Davids channel. That channel has probably a depth similar to or greater than that of the part now constituting the whirlpool basin. Now, if, as we have reason to believe, this old channel was formed by an obsequent stream of moderate volume flowing northward to the Ontario lowland, it can hardly be assumed that there was but one continuous fall of from four hundred to five

Plate 10



The Whirlpool rapids and American bank, looking north. The talus above the gorge road covers the upper Medina sandstones and shales. The lowest projecting ledge consists of the two Clinton limestones; the talus above that covers the Rochester shales, and the upper cliff is of Lockport limestone. The upper gray Medina projects in one place, and shows the Clinton shale above it.

hundred feet in hight, with such a pronounced alternation of hard and soft layers. We must rather assume that a separate fall existed over each hard layer, and that, as in the other streams flowing northward over these same strata, these falls were separated from one another by considerable distances. If then, as is clearly indicated by the quartzose sandstone ledge at the inlet to the whirlpool, the lowest of these falls was at that place, the other two or three must have been at some distances up stream, and in that case it is not too much to assume with Pohlman, that the upper old falls over the Lockport limestone were somewhere near where the gorge is now spanned by the railway bridges. Taylor, however, does not encounter this difficulty, for he assumes that the St Davids gorge was formed by an interglacial Niagara, the great cataract of which, just before its cessation (probably through a southward diversion of the drainage) plunged as a single fall over the cliff into the basin now holding the whirlpool. To this view it may be objected that the old St Davids gorge is not such as would be formed by a single great cataract, since it flares out northward, having a width at St Davids of perhaps two miles. Such a form is more readily accounted for if one assumes that the valley was made by the headward gnawing of an obsequent stream and its various branches. Taylor meets this objection by invoking the action of readvancing ice to broaden the gorge, but, unless the last ice advance was from a very different direction from that indicated by the striae of this region, this hypothesis will scarcely hold. That direction, as already noted, is 30° west of south, while the direction of the old gorge is almost due northwest. Why may we not assume that only a portion, the southern one of the gorge of the whirlpool rapids, was carved by the Niagara during the time that its volume was diminished, and that the greater portion of this gorge was preglacial? This would greatly reduce the length of time during which the upper lakes discharged by way of the Nipissing-Mattawa river, though probably leaving time enough for the waters from these lakes to produce all the erosion features found in this ancient stream channel. This would still leave the Eddy basin to be accounted for, a difficulty which may perhaps be diminished by assuming that the second of

the ancient falls was situated at the point where the gorge contracts to the width of the narrower channel of the whirlpool rapids.

It will thus be seen that this interesting problem of the origin of the gorge of the whirlpool rapids, propounded nearly 20 years ago by Dr Pohlman, is by no means wholly solved. We may return to the original solution of the propounder of the question or we may find new evidence which will corroborate Taylor's explanation. And who shall say that still other explanations of these features may not be forthcoming in the future, when those now demanding attention will be no longer regarded as plausible or sufficient?

The upper gorge and the falls

PLATES 1, 2, 4, 5, 11

Whatever may be believed with reference to the narrow gorge of the whirlpool rapids, most observers agree that the broad and deep gorge from Clifton to the present falls was made by a cataract carrying the full supply of water. This, the latest and most readily interpreted part of the gorge, has come to an end at the Horseshoe falls of today, and the character of the channel hereafter to be made can only be conjectured. The river has reached another of its critical points, where a rectangular turn is made, and it is not improbable that, as at the other turns, so here the character of the gorge will change. Already a short channel, considerably narrower than that of the last preceding portion, has been cut by the Horseshoe falls. (Fig. 19) This narrowness of the channel is due to the concentration of the water at the center of the stream. It is easy to see that Goat island and the other islands owe their existence to this concentration of the water; for at one time, as shown by the shell-bearing gravels, these islands were under water. The channel above the Horseshoe falls has been cut more than 50 feet below the summit of Goat island at the falls, while the upper end of the island is still at the level of the water in the river.

Goat island lies on one side of the main mass of forward rushing water, which passes it and strikes the Canadian bank, from which it is deflected toward the center of the cataract, which portion is thus deepened and worn back most rapidly. The directions of the cur-

The Horseshoe Falls with Goat Island and the Three Sisters, as seen from the Canadian side. This view illustrates the narrowness of the gorge now forming.

rents may be seen from the upper walks in the Canadian park, and the effectual erosion of the banks may also be observed. In many cases the shores have been ballasted and otherwise protected against the current. During an earlier period, when the falls were situated farther north, and before the central part of the stream had been deepened to its present extent, the water, then at the level of the river above Goat island, flooded what is now the Queen Victoria

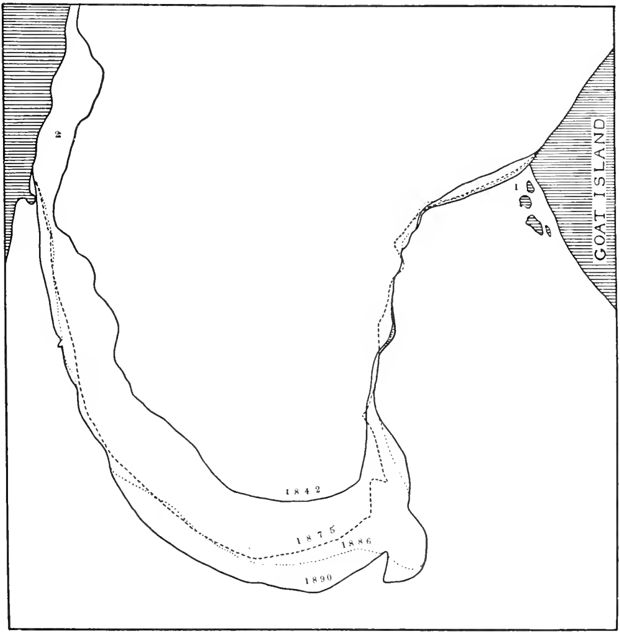


Fig. 19 Crest lines of Horseshoe falls. From the original tracing of the surveys by courtesy of the New York state engineer and surveyor. 1 Terrapin rocks. 2 Former Table rock.

park, and carved from the till the pronounced concave wall which now bounds the park on the west. A local eddy, probably during very recent times, carved the steep and still fresh semicircular cliff which incloses the Dufferin islands.

The fate of Goat island is not difficult to foresee. In a thousand years from now, at the present rate of recession, the Horseshoe falls

will have reached the upper end of the island and will draw off all the waters from the American falls, which by that time will have receded only about half way to the Goat island bridge. All the islands will then be joined by a dry channel to the mainland, an event which was anticipated in the year 1848, when, owing to an ice blockade in the Niagara river near Buffalo, the American fall was deprived of all its waters for a day. As already indicated by Gilbert's forecast, in from two to three thousand years from now, or long before the falls have even reached the head of Grand island, the drainage of the great lakes will be reversed, provided the land continues to rise northward as it has in the past, and Niagara will carry only the drainage of the immediate neighborhood. From a majestic cataract it will dwindle to a few threads of water falling over the great precipice, such as may be seen during the summer season in the upper falls of the Genesee at Rochester.

Age of Niagara

Speculations as to the age of Niagara have been indulged in ever since men began to recognize that the river had carved its own channel. The length of time required for the excavation of Niagara gorge is not merely of local interest but serves as a basis for estimating the length of time since the disappearance of the Laurentian glaciers from this region, and incidentally it has served as a chronometer for approximately measuring the age of the human race on this continent. From insufficient data Sir Charles Lyell estimated the age of Niagara at 36,000 years, while others have assumed an age as high as 100,000 years or more.

No reliable basis for estimating the age of the gorge was known till a series of surveys were made to determine the actual recession of the cataracts. From these the following variable rates of recession of the two falls have been obtained.[1]

[1] Report N. Y. state engineer. 1890.

The American falls

	Feet a year
From 1842 to 1875	.74
1875 " 1886	.11
1886 " 1890	1.65
averaging	
From 1842 to 1890	.64

The Horseshoe falls

From 1842 to 1875	2.01
1875 " 1886	1.86
1886 " 1890	5.01
averaging	
From 1842 to 1890	2.18

This shows a most rapid increase in the rate of recession during the four years between the last two surveys. From this we may assume that the mean recession of a cataract combining the volumes of both American and Horseshoe falls, such as existed throughout the greater period of gorge excavation, is at least three feet a year and may be as high as four or even five feet a year.

The first to make use of this known rate of recession in estimating the age of the gorge was Dr Julius Pohlman. He considered that the gorge of the whirlpool rapids and other portions of the present gorge were of preglacial origin, and so reduced the length of post-glacial time to 3500 years. Since that time numerous estimates of the age of the gorge have been made, the results often varying widely, owing to different interpretations given to the narrow portions of the gorge. It is perfectly evident that, if Niagara was deprived of seven eighths of its water supply, for the period of time during which the gorge of the whirlpool rapids was excavated a very slow rate of recession must have obtained, and hence the age of the gorge is greatly increased. Upham, who does not believe in the withdrawal of the waters, makes the age of the gorge between 5000 and 10,000 years. Spencer and Taylor are ardent advocates of the reduction of the volume of water during a prolonged period, when the supply from the upper Great lakes was cut off.

The former makes the age of the gorge in round numbers 32,000 years, the latter places it tentatively at 50,000 years, though recognizing the uncertainty of many of the elements which enter into his calculations. Prof. G. F. Wright has recently applied a most ingenious method to the solution of this question, and one which seems to eliminate the doubtful factors.[1] This method is based on the measured rate of enlargement of the oldest part of the gorge by atmospheric action. The present width of the river at the mouth of the gorge is 770 feet, and Prof. Wright thinks that it was probably not less at the time when the formation of the gorge began. Assuming that the bank at that time was vertical, he finds that since then the stratum of Lockport limestone at the top has retreated 388 feet. Careful measurements show that the total amount of work accomplished here by the atmosphere since the beginning of gorge formation, was the removal from the side of the gorge of a mass of rock constituting in section an inverted triangle 340 feet high and with a base of 388 feet. This would be similar to a mass with a rectangular section of the same hight but with a base 194 feet wide. The rate of waste of the banks was measured by Prof. Wright as accurately as possible and found to be over one fourth of an inch a year, or a total amount of 610 cubic yards of rock from one mile of the gorge wall. From this he finds that 10,000 years is the maximum amount of time required for the entire change which has occurred in the bank since it was left exposed by the recession of the cataract.

The most recent and most detailed estimates of the age of the gorge have been made by Prof. C. H. Hitchcock.[2] He assumes that the present rate of recession is four feet annually, and finds accordingly that the last formed section of the gorge, from the present falls to the point where it suddenly contracts above the railroad bridges, was formed during 2962 years, which closely agrees with Pohlman's estimate. Thus the beginning of the great cataract at the northern end of the upper great gorge "dates back to 1062 B.C., 300 years before the time of Romulus, or

[1] Pop. sci. monthly. 1899. 55:145-55.

[2] Am. antiq. Jan. 1901.

to the reign of King David at Jerusalem." Prof. Hitchcock believes that the gorge of the whirlpool rapids was formed while Niagara drained only the diminished Lake Erie, and he allows a period of 7800 years for the accomplishment of this task. For the erosion of the remaining portion of the Niagara gorge Prof. Hitchcock allows 8156 years. Thus the total length of time required to carve out the Niagara gorge is considered by Hitchcock to be 18,918 years.

The reader should here be reminded that all such estimates are little more than personal opinions, and that they necessarily vary according to the individual predilections as to greater or less power of erosion possessed by the cataract under the given circumstances. The leading questions concerning the extent of the preglacial erosion in this region, and the changes in volume of water during the lifetime of the Niagara, which are of such vital importance in the solution of this problem, are by no means satisfactorily answered. Nor can we assume that we are familiar with all the factors which enter into the equation. There may be still undiscovered causes which may have operated to lengthen or shorten the lifetime of this great river, just as there may be, and probably are, factors which make any estimates of the future history of the river and cataract little more than a mere speculation. We may perhaps say that our present knowledge leads us to believe that the age of the cataract is probably not less than 10,000 nor more than 50,000 years.

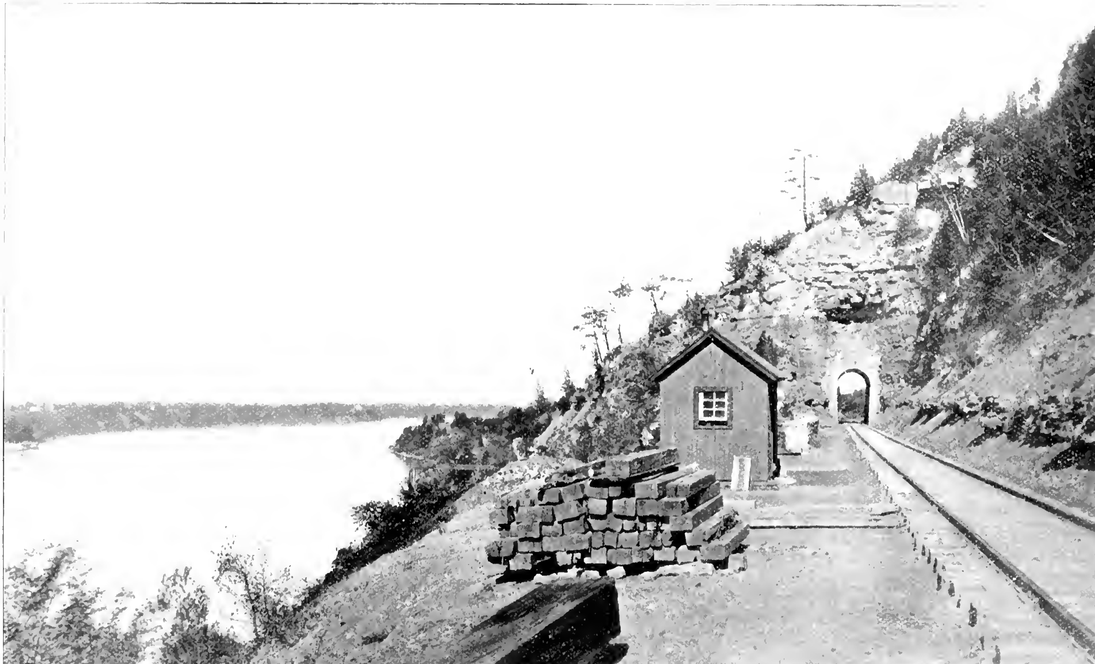
Chapter 3

STRATIGRAPHY OF THE NIAGARA REGION

The stratigraphy of the Niagara region, or the succession of fossiliferous beds, their origin, characteristics and fossil contents, has since the time of Hall's investigations barely received cursory attention from American geologists, whose interest has chiefly centered in the problem of the physical development of the gorge and cataract. A careful examination of the strata of this region and of their fossils reveals problems as interesting and profound as those furnished by the gorge and cataract, and many of them are of far more fundamental and far-reaching significance. Profoundly interesting and instructive as is the " Story of Niagara " and of the physical development of the present surface features, it becomes insignificant when placed by the side of that great history of the rise, development and decline of vast mlutitudes of organic beings which inhabited the ancient seas of this region and whose former existence is scarcely dreamt of by the average visitor to the falls. These ancient hosts left their remains embedded in the rocks of this region; and from the record thus preserved the careful student is able to read at least in outline the successive events in the great drama which was enacted here, in an antiquity so remote that it baffles the imagination which would grasp it. But he who would decipher these records must bear in mind the maxim of La Rochefoucauld: "*Pour bien savoir une chose, il faut en savoir les détails.*" A knowledge of details is necessary to an understanding of the stratigraphic and paleontologic history of this region, and there is no better way of obtaining this knowledge than by a close study of the various sections which expose the strata here described.

The strata of the Niagara region belong to the Siluric series of deposits, which accumulated during the Siluric era of the earth's history.[1] Rocks of Devonic age occupy the southern portion of the district, resting on and concealing the Siluric strata which dip beneath them. (*See* fig. 1, p. 19) As has already been noted, all

[1] *See* table in chapter 2.



Tunnel through Medina sandstone; New York Central railroad cut, looking north. First shanty and remains of first Lewiston suspension bridge are shown.

the rocks of this region have a gentle southward dip, which permits the lower members to appear progressively as we proceed northward over the surface of the old erosion plane. We may now proceed to describe the various members of this series in ascending order.

Oswego sandstone

This, the lowest member of the Siluric, is not exposed in the Niagara region, as its point of outcrop is now covered by the waters of Lake Ontario. (*See* sections 1 and 2, fig. 7) From borings, however, we know its character and thickness, which in this region is 75 feet.

Medina sandstones and shales

Only the upper portion of this formation is exposed in the Niagara district, where the total thickness is more than 1200 feet.

Red Medina shales. The upper beds of this division are the lowest exposed beds in this region. They are bright red sandy shales, generally of a very uniform character, though occasionally a bed which might almost be called a sandstone occurs. Wherever this rock is exposed to the atmosphere, it rapidly breaks down into small angular fragments, which quickly form a debris slope or talus at the foot of every cliff. In the faces of the older cliffs this rock is so friable, that it can readily be removed by the hand, the fragments themselves being easily crushed between the fingers. In the course of time these fragments disintegrate into a fine reddish clay soil, which when wet has a rather tenacious character.

As the lower part of the Niagara river from Lewiston to Lake Ontario is wholly excavated in this rock, it may be seen wherever the banks are kept fresh by the river, or where small lateral streams enter the Niagara. Where erosion is not active, the shale bank is soon reduced to a slope of red clayey soil, which generally becomes covered with vegetation.

A good place for the study of this shale is on the New York side of the Lewiston suspension bridge, where a fresh cut reveals about 50 feet of the rock. The bridge is 65 feet above the river, and the total thickness of red shale above the water at this point is therefore 115 feet. The shale here as elsewhere will be found to be seamed

by whitish or greenish bands, both parallel with and at right angles to the stratification plane. In the latter case they are seen to lie on both sides of a joint fissure, which indicates that the discoloration of the rock, often extending to an inch on either side of the joint, is due to percolating air and water, the latter probably carrying organic acids in solution. The horizontal bands, often several inches in thickness, are probably similarly discolored portions along lines of greater permeability.

No fossils have been found in these shales.

Gray quartzose sandstone. The red shales terminate abruptly and are succeeded by a stratum of gray quartzose sandstone, which is very resistant, and wherever exposed, produces a prominent shelf. This rock varies somewhat in different portions of its exposure, but it averages perhaps 25 feet in thickness. This bed is exposed along the gorge from its mouth to the whirlpool, where it forms a ledge at the water's edge, beyond which it passes below the water level. It is well shown at Niagara glen, where a spring of cool water issues from beneath it, near the water's edge. In the bank on the opposite side, where a fine section of the rocks of the gorge is shown, this quartzose bed is seen in its full thickness, lying between the red shale below and the shales and sandstones above. The red shale at the water's edge has crumbled away, leaving the quartzose bed projecting from the wall in some cases to a considerable extent.

The quartzose sandstone usually forms beds of considerable thickness in this region, though near the top of the stratum a number of thin beds generally occur. The best exposure for the examination of this rock is in the quarries opened up in the terrace on which the Lewiston tower of the suspension bridge stands. In these quarries the sandstone slabs often show smooth surfaces, which generally bear markings similar to those formed by waves on a surface of fine sand. These wave marks are found in most of the sandstones of the Medina group, but they are nowhere in this region so well developed as in the upper thin bedded layers of the quartzose sandstone. No fossils have as yet been found in the gray sandstone on the Niagara river, though farther east a similar quartzose rock shows shells of the Medina *Lingula* on the surfaces of the layers, which also show wave marks.

The succeeding beds of the Medina as well as the Clinton, Rochester and Lockport beds, are best exposed along the railroad cut of the Lewiston branch of the New York Central and Hudson River railroad. This cut is reached from the Lewiston end through a short tunnel cut in the Medina sandstone (plate 12). As the beds dip southward, and the roadbed rises in the same direction, we pass rapidly across all the formations from the lowest to the highest exposed.

Upper shales and sandstones. The contact between the quartzose sandstone and the overlying Medina shales is not generally well exposed, except in one place. This is in Evan's gully, the first of the small excavations in the roadbed, made by the streams of water which in the spring time cascade from the banks. The quartzose sandstone forms the bed of the gully below the bridge on which the railroad crosses it, and it also forms the capping rock over which the stream cascades to a lower level.

1 The lowest beds of this division of the Medina are gray shales, 25 feet in thickness and readily splitting into thin layers and generally smooth to the touch, indicating the absence of sand. There are however beds of a more sandy character, even to fair sandstones, interbedded with the shales, and this is particularly the case near the middle of this shale mass. These sandstone beds are similar in character to the quartzose sandstone below the shales, but they occur in thin layers, separated by shaly masses. These same beds are exposed in the cutting which leads to the tunnel on the north, where they are shown near the base of the section. They vary in thickness up to 8 inches, and in some cases contain a few fossils, notably the shells of Lingula cuneata (fig. 81). The shales below the sandstone layers are mostly below the level of the roadbed, the greatest thickness exposed above that, being about 6 feet.

The upper 13 or 14 feet of this shaly series are well shown in the cutting north of the tunnel, where they may be seen above the sandstones just alluded to. These rocks present in places an almost perpendicular wall, where the overlying sandstones have not been removed, while from the rapid weathering of the shale, the capping stone generally projects beyond the face of the shale cliff. The un-

dermining of the upper layers thus results in their ultimate breaking down from non-support, and the resulting fall of rocks may be of a dangerous character. Care is therefore necessary in the examination of these sections, and the warnings of the section guards should always be heeded. These men patrol the tracks continually from early morning till after the last train has passed at night. This is necessary, as the fall of rocks is continuous, and often of such amount as to obstruct traffic for some time. Any one who will watch these cliffs for a time from one of the projecting points where a comprehensive view may be obtained, and note the almost incessant fall of rock particles, will receive an impressive object lesson in the processes by which cliff retreat is effected.

In many cases the shale banks are covered with a coating of red mud carried by rains from the red soil above them. This creates the impression that the color of these lower shales is red like that of the shales higher up in the series, and only after breaking off fresh particles can the true color be seen.

2 These gray shales are succeeded by sandstones and sandy shales, some of the former massive, quartzose and in beds 6 or 7 inches in thickness, separated by shaly layers. The sandstone is gray and often porous, as if it had undergone some internal solution, which suggests that fossils may have been present which were dissolved by percolating waters. Fragments of fossils are occasionally found, but mostly in an unidentifiable condition. Many of the thinner and more clayey beds have raised markings on their under side, which may be indicative of the former presence of seaweeds in the muddy beds of this period. Small black phosphatic pebbles, often very smooth, are not uncommon in some of the layers, and larger masses of black, apparently carbonaceous shale are occasionally found mixed with the sand. In the gray shaly sandstone beds the Medina gastropods and bivalves (pelecypods) occur sparingly, and usually in a poor state of preservation. Some of the thin layers are calcareous, though still containing a large proportion of argillaceous matter. These are generally fossiliferous, the most common organism being a small cylindric bryozoan.[1] Fragments of these

[1]Identified provisionally as Helopora fragilis (fig. 74).

beds with the bryozoan weathered out in relief on their surfaces, may be found at the base of the cliff in the cut north of the tunnel.

3 In the northern end of the section the sandstones and sandy shales have a thickness of about 5 feet, and are in turn succeeded by 6 feet of shale, weathering readily into a clayey earth, which accumulates, as a talus on the underlying sandstone ledges. As in the other shale cliffs, so here weathering causes a more rapid retreat of the shale than of the overlying sandstone, which therefore projects beyond the shale cliff till it breaks down.

These shales are mostly gray, sometimes greenish gray, with occasional sandstone bands. Toward the top they become intercalated with reddish bands, and finally the prevailing color of the shale becomes red.

4 Following these shales is a mass of sandstone from 35 to 40 feet thick and consisting mostly of beds which vary from 4 to 6 inches in thickness. The sandstone is compact and solid, reddish in color or gray mottled with red. The beds are separated by red shaly partings, with occasional beds of red shale 2 to 4 feet thick. About 20 feet above the base of this sandstone mass is a concretionary layer from 1 to 2 feet thick, which appears not unlike a bed of large rounded boulders. These concretions vary in size up to 3 or 4 feet in greatest diameter, and they lie in close juxtaposition, not infrequently piled on each other, thus still more simulating the blocks of a boulder bed.

This sandstone cliff is in general quite perpendicular, and the thin and comparatively uniform layers, which are regularly divided by vertical joint fissures, produce the appearance of a vertical wall of masonry, for which many people, seeing it only from the rapidly moving train, have no doubt mistaken it. The regularity of these successive beds is at times interrupted by a heavier layer, either red or gray and mottled, which may be traced for some distance, after which it thins out and disappears. This thinning out of the layers in one or another direction is a common and characteristic feature of these sandstones, and is a direct result of the irregularities of current action during the deposition of the sands. We may trace a sandstone mass for some distance, and then find

that it disappears by thinning, either bringing the layers above and below it in contact or giving way to a bed of shale.

A careful examination of these individual beds will show the presence of ripple marks in many of them. This indicates moderately shallow water during the accumulation of these sands; for ripple marks are found only down to the depth to which wave action penetrates. These ripples vary greatly in size, a bed about 10 feet above the concretionary layer showing examples in which the crests are from one to one and a half or more feet apart.

The fossils found in these sandstones are the characteristic Medina pelecypods, and the common Medina Lingula cuneata.

5 The thin bedded sandstone layers are followed by 12 or 15 feet of massive sandstones in beds from one to several feet in thickness, and varying in color from reddish to grayish. This rock generally shows strongly marked cross-bedding structure on those faces

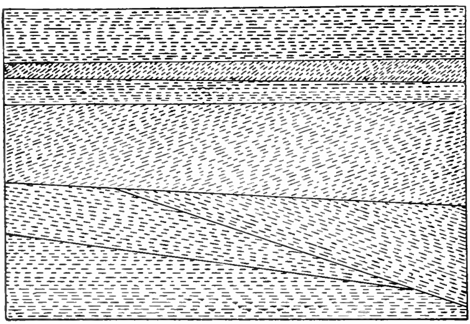


Fig. 20a Cross bedding in Medina sandstone, Niagara gorge.

which have been exposed for some time. This structure illustrated in figure 20a, copied from a ledge of this rock, indicates diverse current and wave action in the shallow water in which this rock was forming. While the deposition of the strata was essentially horizontal, the minute layers made up of the sand grains were for a time deposited at a high angle, much after the manner of deposition of the layers in a delta. After a while the activity of the current changed to another direction, and the layers already deposited were in part eroded, or beveled across the top, and new layers, inhar-

Plate 13

Section on New York Central railroad cut south of first shanty, looking south. Medina sandstone at base; gray band of upper Medina; Clinton shales and Clinton limestones are shown.

monious with the preceding ones, were laid down on the eroded surface. This was repeated a number of times, as is shown by the succession of changes in the sandstone layers.[1] This structure is sometimes shown on a large scale, as in the case of a bed shown about 200 feet north of " Milk cave ravine ", the second of the small ravines met with in coming from the north. Here some of the layers are very gently inclined, and may be traced for some distance. They are obliquely truncated, other horizontal beds resting on the truncated edges (fig. 20b). (*See also* plate 14)

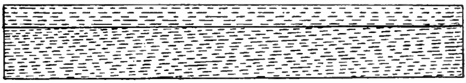


Fig. 20b Contemporaneous erosion and deposition in Medina sandstone, Niagara gorge.

The Medina Lingula (L. cuneata) is found in these sandstones as in the lower ones, but other fossils are rare. Occasionally on the sections the hollows left by the removal of the shells may be seen, while similar cavities, caused by the removal of small black pebbles like those found in the lower layers, also occur. In the upper portions of this mass, on the under side of some thin sandstone lenses resting on and separated by shaly partings, occurs the so-called "jointed seaweed" of the Medina formation, known as Arthrophycus harlani, and illustrated on plate 16. This is a characteristic Medina sandstone fossil, but in this region it has not been found in any of the other sandstone strata. Specimens of this fossil were obtained in digging the great power tunnel at Niagara, but only from the sandstone layers near the bottom of the tunnel, which is about the horizon in which they are found in the gorge section.[2]

6 The highest member of the Medina in this region is a hard, massive bedded and compact quartzose sandstone similar to the

---

[1] Compare with this the cross-bedding structure shown in the unconsolidated sands and gravels in the Goat island gravel pit, and in the section of the old Iroquois beach at Lewiston.

[2] The restriction of this characteristic Medina fossil to these upper layers of sandstone at Niagara was pointed out to me by John MacCormick, the watchman of this part of the road, who collects these specimens and keeps them for sale. As he is continually handling these rocks and has handled them for years, he has become familiar with their characters, and is therefore in a position to obtain knowledge of such facts.

quartzose bed terminating the lower shales. While nearly white when fresh, this rock generally weathers to a grayish yellow color and often exhibits yellow iron stains. On the weathered edges cross-bedding structure is well brought out. When separated from the rocks below by a shaly bed, this rock generally projects from the bank for a sufficient distance to form a shelter for the watchman in case of a sudden shower. Where this sandstone comes down to the level of the roadbed, at a projecting cusp of the cliff, it has been cut through and a portion of it left between the track and the gorge. In the shadow of this rock mass stands the second of the watchmen's shanties which we meet with in approaching from the mouth of the gorge.[1] The upper quartzose bed has here a thickness of 7½ feet. Several hundred feet south of this point, where the top of this sandstone is level with the roadbed, a huge ripple, 15 feet from crest to crest, and nearly 2 feet deep, is shown on the river side of the track. This "giant ripple" was described and illustrated by Gilbert,[2] who found other ripples of similar size in the Medina sandstone at Lockport, as well as in the quartzose sandstone near Lewiston.

On the surfaces of the flagging stones which are derived from the Medina sandstones, ripple marks of small size are not uncommon, and the sidewalks of Buffalo and other cities where this rock is utilized, often exhibit fine examples of such rippled rock surfaces.

In the cliff of Milk cave falls (or St Patrick's falls), which is the second lateral fall below the mouth of the gorge, the upper beds of the Medina formation are well shown. The concretionary layer is near the level of the roadbed, and has a thickness of 3 feet. 29 feet above it is the base of the upper gray quartzose sandstone, before reaching which we find that the red sandstone gradually loses its bright color, at first being mottled, and then at times losing its red color altogether, though the thin partings of shale still retain

[1]This is occupied by John Garlow, on whose beat most of the "Niagara crinoids" (Caryocrinus ornatus) are to be found. Specimens may generally be obtained from him at a small price.

[2]Bul. geol. soc. Am. 10:135-40, pl. 13, fig. 2.

it. The quartzose capping rock consists at the base of a white bed, from 1½ to 2 feet thick and showing cross-bedding structure, followed by shale 1 to 1½ feet thick and of a reddish color in places, and finally by a solid bed of white quartzose sandstone 5 feet in thickness, and like the lower bed, showing cross-bedding structure on the weathered sections. A few thin layers of sandstone overlie this bed, having a total thickness of less than half a foot. On these follow the shales of the Clinton formation.

The upper Medina sandstones and shales may be traced in both walls of the gorge nearly to the falls. From the southward dip, the beds progressively pass below the water level, till near the falls only a small portion of the upper beds remains. These may be seen at the river margin in the bottom of the gorge, between the *Maid of the Mist* landing and the carriage bridge on both sides of the river. On the New York side only a few feet of the red sandstones are exposed, the remainder being covered by talus. During high stages of the river these exposed beds are covered by the water. On the Canadian side an extensive ledge of the red Medina sandstone is exposed opposite the inclined railway on the New York side. In the banks behind this ledge the white quartzose sandstone which forms the top of the Medina occurs, its top being at least 25 feet above the water level. It here forms a projecting shelf on which rest huge blocks of limestone broken from the cliff above. From this we may judge that at the foot of the Horseshoe falls the upper layers of the Medina may still be above the water level.

Clinton beds

The Clinton beds at Niagara aggregate about 32 feet in thickness and consist of a stratum of shale at the base and two distinct strata of limestone above this. (*See* Plate 14)

Clinton shale. Resting immediately on the quartzose layers which terminate the Medina formation, is a bed of olive green to grayish or sometimes purplish gray shale, which readily splits into very thin layers with smooth surfaces, and is quite soft enough to be easily crumbled between the fingers. Fossils are rare in it, but occasionally layers are found which have their surfaces covered with

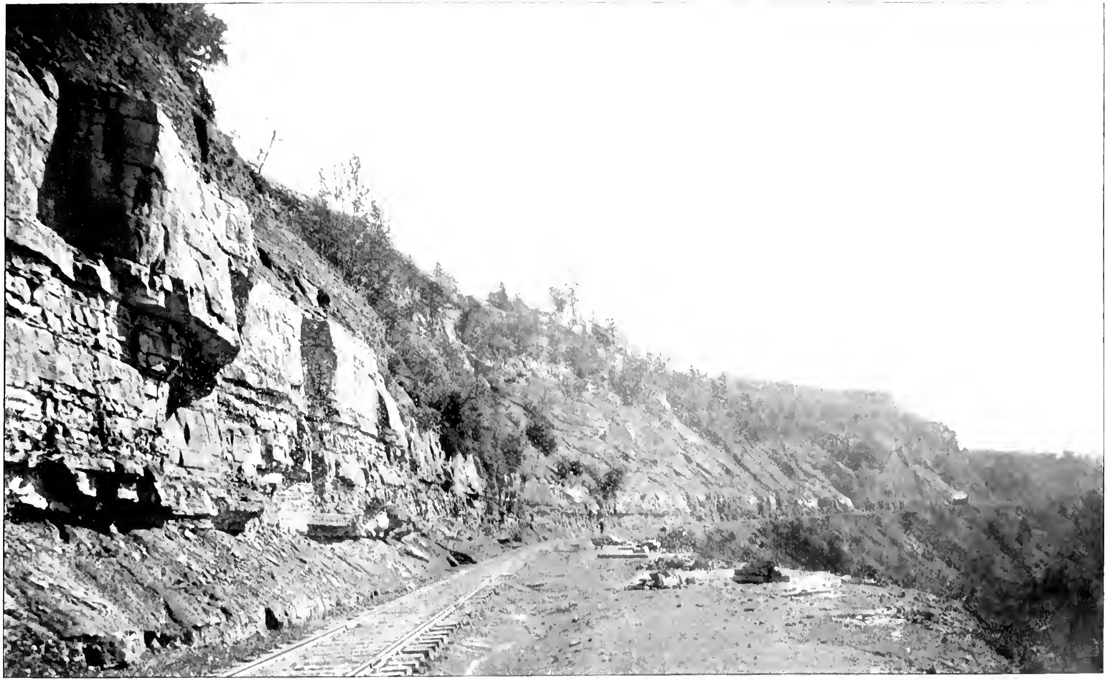
crushed valves of small plicated brachiopods, among which Anoplotheca hemispherica and A. plicatula may be mentioned. Other fossils are rarely found except reed-like impressions which are not uncommon. Some impressions have been found which probably belong to Pterinaea emacerata, a pelecypod occurring higher in the Clinton and also in the Rochester shales. The total thickness of these shales is 6 feet.

Clinton lower limestone. On the shale rests a stratum of limestone $14\frac{1}{2}$ or 15 feet in thickness. The lower three or four feet of this rock are compact to granular or finely crystalline, having a sugary texture. Small masses of iron pyrites are not uncommon in this rock, this being the only representative of the ferruginous matter so characteristic of this part of the Clinton beds on the Genesee river and eastward, where a well marked bed of iron ore succeeds the shale. Hall[1] states that "the lower part of the limestone, as it appears on the Niagara river, is highly magnesian, and from the presence of iron pyrites rapidly decomposes, giving rise to the production of sulfate of magnesia, which at favorable points along the overhanging mass upon the river bank, may be collected in quantities of several pounds."

Fossils are not uncommon in this division of the Clinton limestone, though the variety is not very great. The most abundant species are a small brachiopod, Anoplotheca plicatula (fig. 133) with a strongly plicated surface, and a larger flat brachiopod, Stropheodonta profunda, which at times seems scarcely more than an impression on the rock surface. The remaining part of this stratum is a massive dark gray limestone with occasional thin bands of a shaly character separating the individual beds. Recognizable fossils are not very abundant in this rock. Many of the thin bedded portions of the lower Clinton limestone contain numerous shining black phosphatic nodules, very smooth and resembling small black pebbles. These are probably concretionary masses, though some have the aspect of being water-worn organic remains. Where the thin limestone layers are covered with a shaly or sandy coating, impressions of the beautiful, little

[1]Rep't 4th dist. 1842, p. 63.

Plate 14



View on the New York Central railroad cut, looking south, just south of the second shanty; the third is shown in the distance. The formations shown are, from below upwards; the top of the upper gray band of the Medina; the Clinton shale; Clinton lower and upper limestone; Rochester shale, and, in the distant cliff, the Lockport limestone.

branching seaweed, Bythotrephis gracilis, may be found. This occurs also on some of the shaly partings of the limestones. The impressions vary from the slender variety of great delicacy to a coarse one in which the frond consists of broad irregular lobes.

This stratum generally forms a vertical wall with the next overlying stratum projecting beyond it.

Clinton upper limestone. In the region of the Genesee river the lower limestone is succeeded by a mass of shale which is generally fossiliferous, and on which lies the upper limestone. In the Niagara region this shale is wholly wanting, the upper limestone resting directly on the lower. The line of separation is however well marked, both by the diverse characters of the two rocks and by the different way in which each resists destruction by atmospheric agencies. The upper stratum is a crystalline and highly fossiliferous limestone, often pinkish in color, though chiefly light gray with yellowish or brownish particles where oxidation has occurred. Portions of the beds consist almost wholly of crinoid stems or joints, which give the rock a coarsely crystalline and sometimes porous aspect. Fossils are abundant in this rock, though the variety is generally not large. The most common species is a rotund variety of the brachiopod, Atrypa reticularis (fig. 112), which is generally very robust and sometimes almost globular in form. Of the other fossils in this rock several Stropheodontas may be mentioned, among them Stropheodonta profunda. A number of rhynchonelloid shells occur, readily recognized by their pointed beaks and strong plications. Among these are some small specimens of Camarotoechia acinus, a species characteristic of the Niagara beds of the west. It is readily recognized by its smooth umbonal area, and its single plication in the mesial depression or sinus, corresponding to which, on the opposite valve occur two plications. Among the more abundant fossils of this rock are smooth elongate and rather strongly biconvex brachiopods of the genus Whitfieldella. The most common is W. intermedia, but other species occur as well. The thickness of this stratum is 11 feet. The upper beds of this series contain species which on the whole are of a strongly marked Niagaran

type, such as Spirifer niagarensis and others. A common brachiopod is Strophonella patenta, a flat, thin, subsemicircular shell with a straight hinge line and fine surface striations.

A characteristic feature of this upper limestone stratum is the strong development of stylolite structures. These stylolites are vertically striated columns, from a fragment of an inch to several inches in length, and ranged on either side of a horizontal suture or fissure plane in the limestone bed. Projecting from both upper and lower beds, they interlock with each other and so produce a strongly marked irregular suture. This structure is characteristic of limestone beds of this type, but its origin is still obscure. Pressure of superincumbent layers of rock seems to have been the chief cause of their production, this pressure acting unequally on the rock mass, from the presence of fossils or from other causes. A characteristic feature is the open suture at the ends of the columns, which gives the layers the aspect of having separated by shrinkage along an irregular plane. The vertical striations indicate motion either upward or downward.

The Clinton limestones may be seen in both banks of the river where not covered by vegetation, from the mouth of the gorge to within a short distance of the falls, near which they are covered by talus. They always form a cliff in the profile of the gorge, the 6 feet of shale below them forming a sloping talus-covered bank, below which there is another cliff formed by the hard upper Medina sandstone, the lower members forming one or more talus-covered slopes down to the quartzose bed of the Medina. This latter is again a cliff-maker, and generally projects from the bank, while the soft red shale below invariably produces a sloping talus-covered bank. Above the Clinton limestones is another slope and talus formed by the soft Rochester shale, above which a precipitous cliff is formed by the Lockport limestone.

At the base of the cliffs, fallen rocks of the Clinton limestones are mingled with those from the overlying Lockport limestones, and care must be exercised in discriminating between these when collecting fossils. Halfway between the third and fourth watchman's

shanties on the railroad, where the top of the Clinton limestone is on a level with the roadbed, this rock was formerly quarried on the river side, and here a good opportunity is afforded to collect fossils from the limestone fragments. Blocks of the various limestones are also seen by the side of the track between the second and third shanties.

At the whirlpool on the Canadian side the Clinton limestones are seen in both banks of the old St Davids gorge, the section on the west showing glacial striae. Near the foot of the eastern wall of this old gorge and on the talus heaps which flank it, are large masses of calcareous tufa often inclosing leaves, moss or other vegetable structures. These masses appear to come from the horizon of the Clinton limestone, though they have not been seen in place, and it is not improbable that a "petrifying spring" carrying a strong solution of carbonate of lime issues from this rock. Springs issue abundantly from between the two members of the Clinton limestone, and they carry lime in solution, as is indicated by the deposit of soft calcareous ooze on the rocks and other substances over which this water flows. On exposure to the atmosphere this ooze will dry and harden. The joint faces of the Clinton limestone are everywhere veneered over with a thin deposit of calcium carbonate.

Limestone lenses of the Clinton. At intervals in the upper Clinton limestone may be seen large lenticular masses of a compact, hard and apparently structureless limestone, often concretionary and not infrequently showing numerous smooth and striated surfaces of the type known as "slickensides" and which are indicative of shearing movements. One of these masses is visible in the bank opposite the third watchman's hut. Its greatest thickness is about 8 feet, and it lies between the upper limestone and the overlying shale, being partly embedded in both. The rock is often cavernous or geodiferous, the cavities when freshly broken being filled by snowy gypsum or grayish anhydrite. Fossils are abundant in this rock.

Several other lenses of this type are visible in the upper Clinton limestone where it is crossed by the Rome, Watertown and Ogdensburg railroad below Lewiston hights. These masses are however

entirely inclosed by the limestone, from which they are differentiated by their structureless character. The lenses exposed on the Rome, Watertown and Ogdensburg road are rich in shells of orthoceratites and shields of trilobites (Illaenus ioxus), while the lens in the gorge yields chiefly brachiopods, the most abundant of which are the smooth Whitfieldellas, the small W. nitida and the larger W. oblata being the most common.

The following species have been obtained from the lens in the gorge:

Brachiopoda

1 Whitfieldella nitida — abundant

2 W. nitida oblata — abundant

3 W. intermedia — common

4 Atrypa reticularis: specimens with strong, rounded bifurcating striae, noded at intervals by strong concentric striae, and apparently intermediate between the typical form of the species as it occurs in the Clinton and upper limestone and A. nodostriata, the most abundant form of the Rochester shales.

5 Atrypa nodostriata; rather common, convex and more elongate than in the shale above, with the plications generally sharper and bifurcating near the front. The pedicle valve has a distinct sinus bordered by strong plications, the corresponding fold being marked merely by strong plications. Anterior margin distinctly sinuate. The nodulations are not well preserved except in specimens from the shaly portions.

6 Atrypa rugosa; several small specimens, both valves very convex, with strongly defined sinus in pedicle valve, in the center of which is a small plication. Plications bifurcate and also increase by intercalation; crossed by strong rugose lines.

7 Rhynchotreta cuneata americana — rare

8 Camarotoechia neglecta — rare

9 Anastrophia interplicata — rare

10 Spirifer niagarensis; common, large and robust, with long hinge line and moderately high area, and strongly incurved beak. The sinus is flanked by two stronger plications and extends to the beak. The plications are flattened on top.

11 Spirifer radiatus; common but generally crushed; with an extended hinge line and form and proportions similar to the preceding species. The striae are fine and flat on top with very narrow interspaces altogether very similar to those covering the plications of S. niagarensis. A scarcely defined plication appears on each side of the sinus in some specimens, and in these the sinus is rather sharply defined and angular at the bottom. In others the sinus is shallow rounded and not definitely outlined by incipient plications. In the more elongated specimens the cardinal angle is well defined, but in the shorter specimens it is rounded.

12 Spirifer crispus rare

13 Spirifer sulcatus rare

14 Dalmanella elegantula; rare and with greater convexity than that of the specimens in the overlying shale.

15 Plectambonites transversalis rare

16 Leptaena rhomboidalis rare

17 Stropheodonta corrugata rare

18 Orthothetes subplanus rare

19 Strophonella patenta rare

Gastropoda

20 Platyostoma niagarensis rare

Trilobites

21 Illaenus ioxus; fragments of caudal and cephalic shields crowded together into masses sometimes of considerable size.

22 Calymene blumenbachi rare

Bryozoa

23 Lichenalia concentrica; common in very irregular and much distorted masses.

Corals

24 Enterolasma caliculus common

Crinoids

25 Eucalyptocrinus; fragments of root stem and calyx.

In the lenses below Lewiston hights the same species except nos. 2, 3, 9, 10, 14, 15, 17 to 20 and 25 have been found. Rhynchotreta cuneata americana has more the features of the same species from the western Niagara than those of the Rochester shale species.

Spirifer crispus is commonly deficient in plications approaching in this respect and in the character of the sinus, S. eriensis from the Manlius limestone. Atrypa nodostriata is robust, convex, with coarse rounded plications and rather faint concentric striations, characters intermediate between A. reticularis of the Clinton and A. nodostriata of the Rochester shale. Besides these species and some not yet identified, the following occur.

Cephalopoda

26 Orthoceras annulatum

27 O. medullare (?) rare

28 O. sp.

Pelecypoda

29 Modiolopsis cf. subalatus?

The origin of these lenses is still obscure. Many of the fossils found in them are characteristic of the Niagara group of the west, but are rare or wanting in the Niagaran of New York. This is specially the case with the trilobites (Illaenus ioxus) and the cephalopoda. Dr E. N. S. Ringueberg many years ago studied these limestone masses as exposed at Lockport and other more eastern localities, and he termed them the "Niagara transition group".[1] He found in this rock 32 Niagara species, 11 species common to the Clinton and Niagara, two species found otherwise only in the Clinton, and two species not found outside of this rock. The origin and significance of these unique deposits are being carefully studied by the state paleontologist.

Rochester shale

The Rochester (Niagara) shale has a total thickness of about 68 feet in the gorge of the Niagara. It is here divisible into a lower and an upper half. The lower portion is a highly fossiliferous shale with numerous limestone bands, and terminates in a series of thin calcareous beds with shaly partings in all about 4 feet thick, and extremely rich in bryozoa. The upper 34 feet are quite barren and have few limestone layers.

[1] Am. nat. 1882. 6:711-15.

Plate 15

View of the New York bank a short distance north of the Devil's hole. The gorge-road is shown below, and the New York Central railroad cut near the middle. The fourth shanty is shown a short distance to the left (north) of the bridge.

Lower shales. The beds immediately succeeding the Clinton limestone are calcareous shales with frequent thin limestone layers. The latter are the most fossiliferous, being in general entirely made up of organic remains. The calcareous beds of the lower 5 or 10 feet are particularly rich in crinoid remains. Chief among these organisms, on account of its abundance and perfection, is the little triangular Stephanocrinus ornatus, which may be found in most of the calcareous layers. Fragments of Eucalyptocrinus are always common, while the characteristic Niagara cystoid Caryocrinus ornatus is also found, though not so abundantly as in the upper part of the lower division. The most abundant brachiopod of the lower shales is Whitfieldella nitida oblata, similar to the specimens found in the limestone lenses. The little Orthis, Dalmanella elegantula, is also common, ranging throughout the lower division of the shales. Spirifer niagarensis is common above the lowest 3 or 4 feet of the shale. Orthothetes subplanus, a large, subsemicircular and nearly flat brachiopod, is abundant in some of the calcareous layers, which at times seem to be composed of it, so thickly are these shells piled one on the other. Atrypa nodostriata is the commonest representative of the genus, the larger A. reticularis, so abundant in the upper Clinton, being comparatively rare and subordinate in development. In the limestone bands A. nodostriata is usually rotund, but in the shaly beds it is most commonly compressed. Trilobites are comparatively rare in these lower shales, though representatives of all the species found in this region have been obtained from them. Bivalve molluscan shells are also uncommon, but the gastropods, Diaphorostoma niagarense and Platyceras are not infrequent.

Some of the calcareous bands are almost barren of organic remains, but in most cases these beds will be found to constitute the chief repositories of the fossils.

Bryozoa beds. A short distance south of the third watchman's hut, the section comes to an end, being for some distance replaced by a soil-covered and more or less wooded bank. Where the section

ends the upper Clinton limestone is only a few feet above the roadbed, and the shale above it is accessible. 29 to 30 feet above the top of the limestone, a group of calcareous beds rich in bryozoa project from the bank, being readily traceable for some distance on account of their compact nature. Their total thickness is about 4 feet, and they consist of numerous thin limestone layers with shale partings of greater or less thickness. On the weathered surfaces of the limestone layers, the bryozoans stand out in relief, and such surfaces will often be found completely covered with these delicate organisms. The cylindric types prevail, but the frondose forms are also common. With them occur brachiopods and other organisms. Slabs of this rock are often found on the talus slopes, and they are among the most attractive objects that meet the collector's eye. The section begins again, after an interruption of perhaps a quarter of a mile, near the old quarry in the Clinton limestone. (Plate 15) Between the river and the railroad are several mounds of shale, which were left in place when the railroad cut was made. These are subject to disintegration, and the fossils in consequence weather out. They may be picked up on these mounds completely weathered out, and often in perfect condition. The best of these mounds is about halfway between the old Clinton limestone quarry and the fourth watchman's hut. Here the top of the mound is on the level of the top of the Bryozoa beds, the whole thickness of which is therefore included in this remaining mass. As these beds are extremely fossiliferous, this mound is a productive hunting ground.[1]

An equally productive locality for weathered-out fossils is the slope of disintegrated shale rising from the Rome, Watertown and Ogdensburg railroad tracks above Lewiston hights. The best hunting ground is in the little gullies made by the rivulets of rain water in the bank. Some glacial till is here mingled with the clay from the decomposed shales, and it requires a little attention to distinguish the two.

[1] The fossils here obtained are extremely delicate and brittle. They should be placed at once on layers of cotton batting, in a small box and covered with similar material, the box being completely filled. This is the only way in which many of these delicate fossils can be carried away without breaking.

Upper shales. Above the Bryozoan beds the shale is soft, and more evenly and finely laminated, splitting often into thin slabs of moderate size. Hard calcareous beds are generally absent, though occasionally found near the top. The stratification and lamination is much more strongly marked in this than in any other division of this rock. When freshly broken, the shale has a brownish earthy color, which changes to grayish when the rock decomposes to clay. Fossils are rare, those found being seldom well preserved. In most cases the shells are dissolved away, leaving only the impressions of the fossil, which from compression become faint, and are not readily recognized without careful scrutiny. The most common remains found in these rocks are bivalve mollusks (pelecypods) and trilobites. Among the former Pterinaea emacerata is the most abundant, while Dalmanites limulurus is the chief among the trilobites of these beds. Other trilobites also occur in these shales, notably Homalonotus delphinocephalus, as well as a number of brachiopods.

Toward the top fossils become rarer, and finally are wanting altogether. The shale becomes more heavy bedded, and calcareous layers begin to increase. The last 10 feet or more are quite calcareous and compact, and have an irregular fracture. They grade upward into the basal layers of the Lockport (Niagara) limestone.

Lockport (Niagara) limestone

The limestone which succeeds the Rochester or Niagara shales forms the summit rock of the series from the edge of the Niagara escarpment to south of the falls. It consists of a number of distinct strata, of varying characters, most of them very poor in organic remains. The total thickness exposed in the Niagara region is not over 130 feet, but borings show that the thickness of the limestone lying between the Rochester shale and the Salina shales is from 200 to nearly 250 feet. Some of the upper beds of this limestone mass may represent the Guelph dolomite and others may belong to the base of the Salina beds. Nevertheless we may confidently assume that the thickness of the Lockport limestone in this region, is at least 150 feet.

Hydraulic cement beds. 1) The lowest stratum of the series is a hard, compact, bluish gray silicious limestone, weathering whitish on the exposed faces, and breaking into numerous irregular fragments larger near the bottom of the stratum but becoming small, angular and subcubical near the top, where the weathering is similar to that obtaining in the upper parts of the shales. This stratum varies from 7 to 8 feet in thickness being in places divided into two tiers, the upper one, 4 feet thick, appearing as a distinct bed. This weathers to a creamy gray color, and breaks into small angular fragments with no regularity of fracture, and independent of the plane of stratification. On some of the weathered edges of this rock irregular stratification lines are visible, giving the beds the appearance of a fine grained sandstone. Occasionally small geoditic cavities occur lined with dolomite or gypsum. The line of contact between this stratum and the underlying shale is an irregular one, the shale surface having a wavy character.

2) This rock is succeeded by a 4 foot stratum of arenaceous limestone which shows no well marked stratification lines on the weathered surfaces, though in places a distinct cross-bedding structure appears. It peels off in irregular slabs parallel to the cross-section, i. e. at right angles to the stratification plane. Near the top of this stratum are a few thin beds which show the finer stratification structure on the weathered edges, the character of this structure being such as is found in fine grained sandstones.

Both these strata appear to be wholly destitute of fossils. It is not improbable however that the scattered geodes represent the places where corals or crinoids occurred, which have subsequently been altered or dissolved out. Aside from this, there is no evidence that this rock ever was fossiliferous, and it is most probable that it represents the accumulation of fine calcareous mud or sand.

Crinoidal limestone. 3) The compact hydraulic rock is abruptly succeeded by a stratum of highly crystalline limestone, on the weathered surfaces of which joints of crinoid stems and other organisms stand out in relief, particularly in the lower part of the stratum. The rock is entirely composed of fragments of organisms which were ground up and mingled together in great profusion. Oblique

bedding lines may be observed occasionally, indicating that the fragments were subject to wave action. The stratum varies in thickness from 5 to 6 feet, and is occasionally divided by horizontal sutures which show a marked stylolitic structure similar to that found in the crystalline upper Clinton limestone. The contact between this and the underlying stratum is wavy. This rock has been quarried at Lockport under the name of Lockport marble.

Geodiferous limestones. The crinoidal limestone is succeeded by strata all of which are more or less geodiferous, though varying considerably in composition and structure.

4) The rock immediately following on the crinoidal bed is a 4 foot stratum of compact, gray fossiliferous limestone, the fossils being of a fragmentary character. Stratification structure is well marked on the weathered surfaces, specially in some of the lower beds of the stratum. Sometimes there is only one thick bed, at others the stratum consists of a number of thin beds with a heavy one near the center. The thin beds show the stratification structure best, having at the same time a strongly granular character. As the fossils are fragmentary, and only accessible on the weathered surfaces, little is known of the organisms that constitute it. Crinoid joints occur, but they are less characteristic of this than of the lower stratum. Geodes however are not uncommon, the cavities being lined with crystals of pearl spar (dolomite) or filled with masses of snowy gypsum.

5) The fifth stratum of limestone in this series is a finely crystalline magnesian rock, like the others destitute of fossils except in so far as these are represented by geodes. The latter are common and filled with alabaster, or sometimes with massive or crystallized anhydrite. The latter is distinguished from the crystallized gypsum or selenite, which it closely resembles, and which occasionally occurs in the same beds, by the cleavage, which is rectangular and nearly equally perfect in three directions in anhydrite, while it is perfect in one direction only in the selenite.

6) A finely crystalline, somewhat concretionary dolomitic limestone, 3 feet thick, next succeeds, the weathered sectional surfaces of which, buff in color, show the fine stratification structure, which

is of the type of the cross-bedding structure in sandstone. Such structure indicates that the bed possessing it was a fine calcareous sand, subject to shifting movements by waves and deposited in moderately shallow water. We need look for organic remains in such a rock with no more assurance of finding them than we bring to the examination of uniform bedded shales. They may be abundant or they may be rare or absent altogether. Thus a limestone need not be necessarily a fossiliferous rock.

Geodes of the usual type are common, the dolomitic lining predominating.

7) On the preceding thin stratum follows a limestone mass of very uniform character, hardly separable into district strata, though consisting of numerous beds.[1] 27 feet of this stratum are shown at the quarry near the northern end of the section, where the upper exposed bed forms the surface rock of the plateau above. The beds are generally of considerable thickness, but the fine stratification structure is not so well marked as in the strata below. The rock may be considered a compact granular dolomite, in which considerable change has taken place since its original deposition. It is of a grayish color but weathers to a lighter tint. Geodes are plentiful, often quite large, and in these, minerals of great beauty are not infrequently found. The most common are the snowy variety of gypsum or alabaster, the darker gray, massive, fine anhydrite and the uniform, fine, dolomite rhombohedra with curved faces, generally of a pinkish tint and familiarly known as pearl spar. Long slender crystals of calcite, generally in the form known as scalenohedra, or dogtooth spar, are not uncommon. These are commonly of a golden color, and large enough to show well their crystal faces. In the new power tunnel which was excavated in the neighborhood of the falls, large masses of transparent gypsum of the selenite variety were found in cavities in this rock. Some of these pieces were 6 inches in length. Masses of limestone lined with pinkish dolomite crystals and occasional large masses of silvery selenite, and set with

[1]The distinction between stratum and bed is an important one. A stratum is a rock mass having throughout the same lithic character, and may be thick or thin. A bed, on the other hand, is that portion of a stratum limited by horizontal separation planes. *See* Geology and paleontology of Eighteen Mile creek pt 1. Introduction.

amber crystals of calcite, were also found in these cavities, the combination being such as to produce specimens of great beauty. Among the rarer minerals found in this rock is the crystallized and cleavable anhydrite, which like gypsum is a sulfate of calcium, but without the water which is characteristic of that mineral. Anhydrite crystallizes in the orthorhombic system, and its cleavage is in three directions, at right angles to each other (pinacoidal), thus yielding rectangular fragments and enabling one to distinguish it from selenite with little difficulty. It is also a trifle harder than selenite which is easily scratched with the finger nail. This form of anhydrite is rather rare, the principal localities for it being foreign. Masses of considerable size have been found in the limestone of this quarry, and small pieces are not uncommon in the geodes of these strata. Both selenite and the cleavable anhydrite are commonly called "mica" by the uninitiated; that mineral however does not occur at Niagara. Small masses of fibrous gypsum or satin spar have been found, but these are very rare. The satin spar of which the cheap jewelry sold in the curiosity shops is made is not from Niagara.

Among the metallic minerals found in this rock, zinc blende or sphalerite is most common. It is generally of a yellowish or light brownish color and brilliant resinous luster. Large masses however are rare. Galenite or lead sulfid crystals are also occasionally found, but this mineral is comparatively rare. In addition to these, iron pyrite, iron-copper pyrite (chalcopyrite), green copper carbonate (malachite), fluor spar (fluorite), iron carbonate or brown spar (siderite, generally ferruginous dolomite), strontium sulfate (celestite) and native sulfur as well as other minerals are met with.

The total thickness of the limestone exposed in this section is thus somewhat more than 55 feet. At Lewiston hights, on the edge of the escarpment, only about 20 feet are exposed. This includes the two lower strata of hydraulic limestone, the crinoidal limestone and a few feet of the lowest geodiferous beds (stratum 4). Over this lie some two or three feet of glacial till. The distance between the edge of the escarpment and the quarry at the end of the section. is a little over a mile and a half, the increase in thickness of the

limestone and the rate of dip (since the surface is about level) is therefore a trifle less than 25 feet in the mile.

The crinoidal limestone is the most prominent stratum on the edge of the escarpment. From its base springs of cold and clear water issue at numerous places along the outcrops, both on the edge of the escarpment and in the gorge. The most prominent of these is at the head of " Milk cave " or St Patrick's falls, and here as almost everywhere at the base of the crinoidal limestone, shallow caverns abound. One of these caverns near the head of the falls, has a depth of 35 or 40 feet and is high enough to permit one to walk upright. No stalactites are found in these caverns, but the walls are much disintegrated and in places covered with a fine residual sand.

In the fields above this cavern are several sink holes of moderate depth, which serve as catchment basins for the waters of the surrounding country, which issue from these caverns during the wet seasons.

The cavern known as the Devil's hole belongs to this category. As in the other caverns, the roof is formed by the crystalline crinoidal limestone (stratum 3), the cavern itself being hollowed out in the hydraulic cement rock. This cavern is deeper than most others, and at the end a spring of deliciously cool water issues from between the two beds, the upper " spring line " of this region. There is no evidence that the cavern extended any deeper than it does at present, nevertheless the spot is worth visiting, as it is the only accessible one of the numerous springs and caverns. The fall of the Bloody run at this place is over a thickness of almost 60 feet of limestone, and the chasm which this stream has worn is interesting both from its historic and scenic points of view.[1]

West of the Niagara river on Queenston hights several quarries have been opened in these limestones, some distance south of the edge of the escarpment. The rock quarried is the crinoidal limestone and overlying beds. The total depth of rock in the quarry is 27 feet, of which the lower 14 or 15 feet are bluish gray and the upper of a lighter gray color. The limestone is here much more uniform, crystalline throughout and more fossiliferous. This may

[1]*See* brief mention of Bloody run massacre in Introduction.

indicate a nearness to the reef of growing organisms which supplied the material for these beds. Geodes lined with dolomite crystals occur in this rock, though not so plentifully as at the quarry in the gorge. Below the crystalline limestone is found the cement rock, which is from 4 to 10 feet thick and is quarried in a tunnel under the limestone quarry.

Owing to the resistant character, the limestone is everywhere exposed in the gorge, forming cliffs which are almost invariably perpendicular. Large blocks of this rock cover the talus everywhere, one of the largest of these being "Giant rock" along the gorge road. This is a block of the upper geodiferous limestone which has fallen from above, and now lies with its stratification planes at an angle of about 45°.

The limestones are well exposed along the gorge road, south of the railroad bridges, but without a special permit no one is allowed to walk on this roadbed. The contact between the limestone and the shale is here very irregular, indications of erosion of the shale prior to the deposition of the limestone occurring. The limestone is also somewhat concretionary, rounded masses projecting down into the shales. The succession of strata is here as follows:

1 Concretionary, irregularly bedded gypsiferous limestone, often earthy and with occasional thin, shaly layers; it splits readily into slabs perpendicular to the stratification. Thickness 6-8 feet.

2 Fine grained limestone with sandy feel, sometimes massive, sometimes in shattered layers with earthy or shaly partings, and separated from the underlying rock by an earthy layer. It weathers to an ashy or sometimes an ochery color, and varies somewhat in thickness. The upper layer is however a solid and fine grained limestone. Thickness 4-4.5 feet.

Strata 1 and 2 are the equivalent of the cement beds.

3 Crystalline and crinoidal limestone abruptly succeeding the lower bed. It is massive though somewhat thin bedded and contains geoditic cavities filled with gypsum. This continues uniform for a thickness of about 19 feet.

4 Compact limestone; concretionary with cavities containing gypsum and other minerals, and with sphalerite embedded in the rock.

The bedding and upper contact lines are irregular. Thickness 14-15 feet.

5 Compact, finely crystalline and homogeneous dolomitic rock, showing traces of fossils and slickensides. Beds showing Stromatopora common. In places the rock has a porous appearance and is rich in geoditic cavities, which are lined with dolomite and calcite crystals. Thickness 19 feet.

This stratum forms the lower portion of the cliff at the first cut on the gorge road, and the basal part of the mass left standing on the river side. Heads of Stromatopora may be seen in this rock, some of the geoditic cavities having replaced this fossil. This is about the summit of the beds exposed in the quarry at the end ot the railroad section.

6 Earthy, compact dolomite in thin layers, which give the cliff the appearance of a stone wall. Toward the top the rock becomes more compact and heavy bedded, this giving the appearance of an overlying stratum. This rock is full of geodes lined with pearl spar or dolomite, the cavities ranging in size up to that of a fist or larger. The beds are generally less than a foot in thickness, the average being from 3 to 6 inches. Toward the top of the cut, the rock becomes more compact and finely crystalline, but otherwise remains similar. Pearl spar geodes remain common to the top. The thickness of this mass, at the beginning of the gorge road, is about 45 feet.

The total thickness of the limestone exposed on the gorge road is in the neighborhood of 110 feet. This is double the thickness found at the quarry, the distance between the two points in a straight line being about three miles or nearly four following the curvature of the river. The rate of increase in thickness, or the amount of dip of the strata is therefore about 20 feet to the mile.

Almost the only recognizable fossils found in these limestones, excepting the crinoid fragments, are the hydro-coralline Stromatopora (concentrica Hall) and the coral Favosites. Both occur in the middle and upper portions of the exposed mass, and may generally be seen in the weathered upper surfaces of the limestone beds. Thus wherever these beds are exposed on the sur-

face, as at the whirlpool on the Canadian side, at the fall of Muddy brook, and near Clifton, these fossils are generally weathered out in relief. They are however not readily separated from the rock. Many of the geodes still show traces of coral structure, which is sometimes shown in the included gypsum.

The limestone is well exposed in the cliff at Goat island, where it has a total thickness of about 110 feet. The contact between the shale and limestone can be seen near the entrance to the Cave of the Winds, where it is about a foot above the top of the stairs. The roof of the Cave of the Winds is formed by the crystalline crinoidal limestone, the same bed which forms the roofs of all the minor caverns along the gorge. The cement beds, about 10 feet thick, together with the 70 feet of Rochester shale, are removed by the spray to a depth of perhaps 30 or 40 feet, the floor of the cave being probably on the upper Clinton limestone, thus making the hight of the cavern 80 feet. Floored and roofed by resisting beds of crystalline limestone, this great cavern is a fit illustration of selective erosion by falling water on rocks of unequal hardness.

The massive limestone which forms the vertical cliff of Goat island is 68 feet thick, its base being on a level with the foot of the Biddle stairway. The top of this cliff marks approximately the level of the falls on either side of Goat island, which therefore have a total thickness of nearly 80 feet of limestone, of which however the lowest 10 feet yield to erosion as does the underlying shale. We may thus say that at the falls there are 70 feet of resistant limestone on top, and 80 feet of yielding shales and limestones below. As the crest of the falls approximates 160 feet above the river below, at least 10 feet of Clinton limestone are found above the water level.

From the top of the vertical cliff at Goat island a sloping bank exposing thin bedded limestones, overlaid by about 10 feet of shell-bearing gravels, rises to a hight of about 40 feet, while on either side of Goat island these thin bedded limestones form the rapids above the two falls. As the total hight of the rapids is about 50 feet, and, as they are formed along the strike of the beds owing to the right-angled turn in the river at this point, the thickness to be added to the known limestone mass is not over 50 feet, giving a total thickness of 130 feet of limestone exposed within this region.

Guelph dolomite

This rock, named from its occurrence at Guelph (Ont.) about 75 miles northwest of Niagara falls, is, so far as known, absent from the Niagara district. As before noted, it may however be represented in the buried hundred feet of limestone (more or less) which lie above the 130 feet of known rock, as shown by the borings in this region.

Salina beds

The basal beds of the Upper Siluric are the saliferous shales and calcareous beds of the Salina stage, so named from the salt-producing village of Salina in Onondaga county. This is the horizon which furnishes all the salt, as well as the gypsum of New York state and the adjoining territory. In the Niagara region this formation is not well exposed, owing to the soft character of the rock which has permitted deep erosion in preglacial times, and to the extensive drift deposits which cover it. The only known exposures on the Niagara are on Grand island and on the Canadian side of the river opposite North Buffalo. On Grand island the Salina rocks may be seen at Edgewater about 200 yards below the boat landing. Here the following section is exposed.[1]

3 Light colored, soft, friable gypseous shales, 5 feet
2 Greenish shales containing nodules of gypsum, 1½ feet
1 Black shale in the river bed

The exposure extends 300 yards down the river bank.

At the extreme northern end of the island, where it divides the river, an impure, thin bedded limestone of this series is exposed. The exposures on the Canadian bank begin a short distance south of this, and extend to the International bridge, the rock here being a more or less gypsiferous shale.

From the numerous borings in this region we have however gained a fair knowledge of the character and thickness of this rock, the latter averaging, according to Bishop, 386 feet. The best available record of the rocks lying between the Waterlime and the Niagara series of limestones is the core of a well drilled on the land of the Buffalo cement co. in North Buffalo. This core, which has a

[1]Bishop. 15th an. rep't N. Y. state geologist. 1895. p. 311.

length of 1305 feet, is now preserved in the museum of the Buffalo society of natural sciences, and from it the following succession of strata can be demonstrated.[1]

		Feet
Rondout waterlime	Waterlime above the mouth of the well, about	7
	Shale and cement rock in thin streaks	25
	Tolerably pure cement rock	5
	Shale and cement rock in thin streaks	13
Salina	Pure white gypsum	4
	Shale	2
	White gypsum	12
	Shale	1
	White gypsum	4
	Shale and gypsum mottled	7
	Drab colored shale with several thin layers of white gypsum	58
	Dark colored limestone	2
	Shale and limestone	4
	Compact shale	3
	Gypsum and shale mottled and in streaks approximating	290±

The gypsum of this formation has never been mined in this district, owing to the strong flow of water through these strata. No salt beds are found in the Salina of this region, though they are characteristic of the formation farther east. Salt water is however obtained. Fossils are very rare throughout these beds; none have been found in the exposures on the Niagara river.

Rondout waterlime

The Salina beds of this region grade upward into a magnesian limestone which contains a considerable amount of aluminium silicate. The upper portion of this series, which in the Niagara region has a thickness of about 50 feet, is very uniform in character and suitable for the manufacture of hydraulic cement. In North Buffalo, extensive quarries have been opened in this rock by the Buffalo

[1] Pohlman. Cement and gypsum deposits in Buffalo. Am. inst. min. eng. Trans. Oct. 1888.

cement co., and here a stratum nearly 6 feet thick is quarried and converted into cement. As the quarries are opened south of the second escarpment (inface of the Onondaga cuesta[1]), the surface rock of Onondaga limestone and the Manlius limestone have to be stripped off before the cement rock is reached.

The characters of the several strata have been briefly enumerated in the section derived from the gas well core. The upper beds, which are alone accessible in this region, may generally be seen in the escarpment, specially where it is crossed by streams, as at Williamsville, or where quarries have been opened. The rock is fine grained, often showing a marked banding or lamination, and breaks with a conchoidal fracture, producing rounded surfaces.

In this rock we find entombed the remains of those remarkable crustacea, the Eurypterids, whose bizarre form, remotely fish-like, has excited more interest than any other fossil found in this region. These Crustacea have made the Waterlime of Buffalo famous, and the Buffalo society of natural sciences, whose collections embrace a magnificent series of these fossils, has fittingly adopted it as chief among its insignia.

Besides these crustacea several other organisms have been found in the Waterlime strata of north Buffalo. Among these are a number of undescribed brachiopods, including at least one species of Lingula.

Manlius limestone

The waterlime of north Buffalo is succeeded by a stratum of impure limestone from 7 to 8 feet in thickness and known locally by the name of "bullhead" rock. The line of demarkation between the two formations is not a very pronounced one, for the inferior rock grades upward into the superior one. The rock is a dolomitic limestone of a very compact semicrystalline character, with a high percent of argillaceous material, and not infrequently a strong petroleum odor. It is mottled, having frequently the appearance of a limestone breccia, and consists of purplish gray, angular or rectangular pieces and similar light colored and more yellowish ones. The latter appear to be more argillaceous than the former. There

---

[1] *See* chapter 1.

is no conclusive evidence that the rock is brecciated, nevertheless the coloration strongly suggests it.

This rock is commonly very porous in its upper portion, the cavities being often lined with crystals of calcite or other minerals. The smaller of the cavities are due to the dissolving out of the small coral, Cyathophyllum hydraulicum, which was exceedingly abundant in the upper part of the stratum. This coral is generally found in a prostrate position, with the mold perfectly preserved in the inclosing rock matrix, so that a perfect cast of the coral can be obtained by the use of gutta percha or dentist's wax. The best exposure of this rock is in the walls of the quarries of the Buffalo cement co. It may also be seen in the face of the Onondaga escarpment at Williamsville and eastward. In many places in the cement quarries, the upper part of this limestone is rich in iron pyrites, which commonly occurs in small cubes, not infrequently oxidized to limonite. Green stains of hydrous carbonate of copper, or malachite, are not uncommon, these resulting probably from the decomposition of chalcopyrite, which is disseminated in minute grains through portions of the rock. Many of the geode cavities contain scalenohedra or acute rhombohedra of calcite, as well as sulfate of strontian.

A remarkable feature of the Manlius limestone of the Niagara region is the nature of the fossil fauna which it contains. This fauna shows an intimate relation to the Coralline limestone fauna of Schoharie county (N. Y.) a rock which is regarded the eastern equivalent of the Lockport (Niagara) limestone of this region. Several of the species found in the Manlius limestone of this region are identical with those of the Coralline limestone, while between other representative species of the two formations there exists a very close relationship. It is difficult to escape the conclusion that the Manlius limestone fauna of the Niagara region is a late return of the Coralline limestone fauna, at the close of the long interval during which the Salina shales were deposited in the Siluric seas of this region.

The Siluro-Devonic contact

The Manlius limestone of the Niagara region is succeeded by the Onondaga limestone of Devonic age. The latter rests unconform-

ably on the former, this unconformity being emphasized by the absence of all Lower Devonic strata in this region, with the exception of thin lenses of sandstone which may be correlated with the Oriskany. The upper surface of the Manlius limestone is knotty and concretionary, producing minor irregularities, but in addition to these there are well marked traces of the erosion of these strata, prior to the deposition of the overlying beds. These traces are of the nature of channels and irregular truncations of the strata, the former in some cases assuming considerable importance. (Fig. 21-23) In the east wall of the quarry, not far from the stamp mill, the surface of the Manlius limestone is strongly excavated, the excavation being mainly filled by beds of the Onondaga limestone. Between the two limestones occurs a mass of shale and conglomerate having a total thickness, in the central portion, of something over a foot. The lower 6 or 8 inches are a limestone conglomerate, the pebbles of which are fragments of the underlying limestones. These pebbles are flat, but well rounded on the margins, showing evidence of protracted wear. They are firmly embedded in a matrix of indurated quartz sand, which surrounds them and fills in all the interstices. This bed thins out toward the sides of the channel. On the conglomerate lie about 6 inches of shale and shaly limestone, and these are succeeded by the Onondaga limestone. The width of the channel, which is clearly an erosion channel, is about 18 feet, and its depth is about $3\frac{1}{2}$ feet. (Fig. 23)

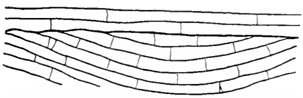


Fig. 21 Unconformable contact between Manlius and Onondaga limestones, Buffalo cement quarry.

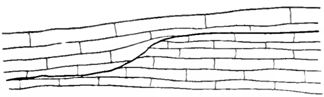


Fig. 22 Erosion of Manlius limestone prior to deposition of Onondaga limestone, Buffalo cement quarry.

From the point where this channel is seen, the contact can be traced continuously for a thousand feet or more eastward, along the quarry wall. It frequently shows a thin shaly bed, often containing quartz grains, lying between the two limestones.

Not very far from the channel just described, a remarkable "sandstone dike" penetrates the Siluric limestones of the quarry wall.

This dike, which can be clearly traced in the wall of the quarry for a distance of perhaps 30 feet in an east and west direction, was

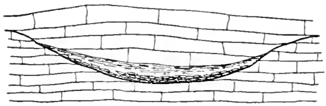


Fig 23 Channel in Manlius limestone with Ortskany sandstone and conglomerate layers, capped by Onondaga limestone, Buffalo cement quarry.

caused by the filling of an ancient fissure in the Siluric strata, by sands forcibly injected from above. The fissure had a total depth of about 10 feet; its walls were very irregular, and at intervals lateral fissures extended in both directions. (*See* Fig. 24) All of these are now filled with pure quartz sand, firmly united into a quartzose sandstone by the deposition of additional silica in the interstices between the sand grains.

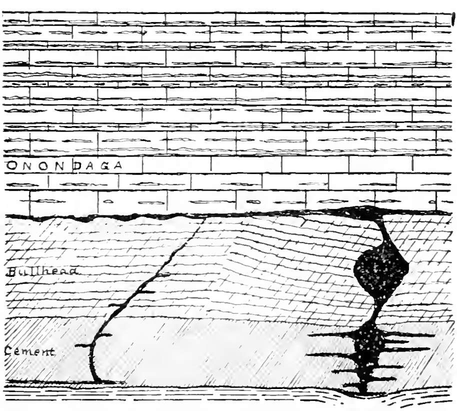


Fig. 24 Sandstone dike in the Siluric strata of the Buffalo cement quarries. (After Clarke)

The dike penetrates the "bullhead" rock and enters the waterlime to a depth of from 2 to 3 feet. It is squarely cut off at the top, where the Onondaga limestone rests on its truncated end and on the limestone flanking it. The Onondaga limestone is entirely unaffected by the dike, being evidently deposited after the formation and truncation of this remarkable mass of sandstone. The width of

the filled fissure is scarcely anywhere over 2 feet, but the lateral offshoots extend many feet into the walls of Manlius limestone. These offshoots or rootlets of the dike are irregular, commonly narrow, and often appear as isolated quartz masses in the Manlius or the waterlime rock, the connection with the main dike not being always discernible. Such masses of quartz sandstone have been traced for more than 30 feet from the dike. The irregularity of the walls of the fissure is very pronounced. Angular masses of limestone project into the quartz rock, while narrow tongues of sandstone everywhere enter the limestone. Extensive brecciation of the limestone has occurred along the margin, and the sandstone there is filled with angular fragments of the limestone, which show no traces of solution or wear by running water. These limestone fragments are themselves frequently injected with tongues of the quartz sand. Microscopic examination shows evidence of a certain amount of shearing along the margin of the dike, accompanied by a pulverizing or trituration of the limestone, and followed by reconsolidation. These and other features point to a cataclysmic origin of the fissure which contains the dike and a more or less violent injection of the sand. The fissure must have been formed and filled before the deposition of the Onondaga limestone and while the Manlius limestone was covered by a stratum of unconsolidated sand. The formation of the fissure and the injection of the sand into it from above must have occurred simultaneously; for this appears the only way to account for the inclusion of large fragments, or "horses", of the wall rock in the loose sand, and the injection of the sand into all the cracks and crevices. It seems probable that the fissure records an earthquake shock during the period intervening between the close of the Siluric age and the deposition of the Devonic limestones. This is borne out by the occurrence of numerous small faults or displacements in the underlying strata of waterlime.

Devonic strata

The Lower Devonic is represented in the Niagara region by the thin beds of shale and sandstone before mentioned as occupying erosion hollows in the Manlius limestone. These are perhaps the

equivalent of the Oriskany sandstone of eastern New York, though no fossils have been found in them. With the exception of these layers the Lower Devonic strata are wanting in this region.

The Middle Devonic is however well represented in the Niagara region by the Onondaga limestone. This rock, which, as has been shown, rests in most cases directly on the Manlius limestone, consists of a lower crystalline and highly fossiliferous portion, and an upper mass full of layers of hornstone or chert which on weathered surfaces stand out in relief. This part of the formation is generally known as the Corniferous limestone, in reference to the layers of chert which make the rock unfit for other use than rough building. Owing to the presence of the hornstone, this rock effectually resists the attacks of the atmosphere, and hence its line of outcrop is generally marked by a prominent topographic relief feature, the second escarpment of western New York i. e. the inface of the Onondaga cuesta.

The chert-free lower member of this formation varies greatly in thickness even within a limited territory. It is in places extremely rich in corals, and outcrops of this rock show all the characteristics of an ancient coral reef.

History of the Niagara region during Siluric time

We have now gathered data for a brief synopsis of the history of this region during Siluric time. Much still remains to be learned, but from what is known we can trace at least in outline the sequence of geologic events which characterized that ancient era of the earth's history in this vicinity.

When the Siluric era opened, New York, with portions of Pennsylvania and southern Ontario, was covered by the shallow Medina sea. This sea appears to have been of the nature of a mediterranean body of water, which later changed to a bay opening toward the southwest. This "Bay of New York", as we shall call it, came into existence by the orogenic disturbances which marked the transition from the Ordovicic to the Siluric era, and as a result of which the Taconic mountain range, with the Green mountains and the corresponding Canadian ranges, were elevated. This cut off the

communication between the open Atlantic and the interior Paleozoic sea which existed during Ordovicic time. This bay was thus surrounded by old-lands on the north, east and southeast, and its waters appear to have been very shallow. We do not know just what the conditions were under which the early Siluric deposits of this region were made: for the lower beds are so barren of organic remains, that we are forced to look for evidences other than that furnished by fossils, of the physical conditions during this period. It is not improbable that the waters of the early Medina sea were cut off from the ocean at large, at least sufficiently to prevent a free communication. This may not have been the case at first; for Arthrophycus harlani flourished in these waters during the deposition of the Oswego beds,[1] and this species characterizes the rocks of late Medina age, during the deposition of which we have reason to suppose that a junction of the Medina sea with the ocean at large had been effected.

Along the eastern and southeastern margin of this interior water body were deposited the thick beds of conglomerate, which now constitute the capping rock of the Shawangunk and other ranges of hills, while farther west, at a distance from the source of supply, the Oswego sandstone was accumulating. Later the character of the deposit changed in this region, from the gray silicious sands to the impalpable muds and fine sands of the lower Medina. Whatever the source of these sands, ferruginous matter was plentiful, as shown by the red color of the deposits, and this leads to the supposition that they were derived from the crystalline rocks of the Adirondacks and the Canadian highlands and not from Ordovicic or Cambric deposits.

It is not improbable that, during the early Medina epoch, the waters of this basin were of a highly saline character. No deposits of salt were formed, or if these existed, they were subsequently leached out. The Medina beds are however rich in saline waters, salt springs being common throughout this region,[2] and this may

[1] This species is found in the eastern part of the district, at the base of the Oneida conglomerate.

[2] In the early part of the century salt was not infrequently manufactured from these springs.

indicate a high degree of salinity of the waters of the early Medina sea. If such was the case, it may have been accompanied by a more or less arid climate, which favored the concentration of the sea water. Thick beds of terrigenous material accumulated in the center of the Medina basin reaching in the Niagara region a thickness of over a thousand feet. These early deposits probably did not extend far west for, though in northern Ohio and Michigan, Medina beds from 50 to 100 feet or more in thickness are known, these are probably to be correlated with the upper Medina of the Niagara region.

Toward the close of the Medina epoch, the Siluric sea had encroached on the lands to such an extent as to effect a junction with the Medina basin, whereupon normal marine conditions were again established. This is indicated by the marine fauna and flora which characterize the upper Medina beds. The first deposit in this region, on the reestablishment of normal marine conditions, was the white quartzose sandstone which caps the red shale of the lower series. Mud and sand now alternated, indicating an oscillation of conditions with numerous changes in the currents which distributed the detrital material. Thin beds of limestones also formed at rare intervals, chiefly from the growth of bryozoans in favorable localities. In the Bay of New York the waters continued moderately shallow, as shown by the well developed cross-bedding structure in the sandstones. At intervals large tracts seem to have been laid bare on the retreat of the tide, as indicated by the wave marks and other shore features which give the surfaces of some Medina sandstone slabs such a remarkable resemblance to a modern sand beach exposed by the ebbing tide. In fact, we may not inaptly compare this stage of the Siluric bay of New York with the upper end of the modern bay of Fundy, where the red sands and muds are laid bare for miles on the retreat of the tide.

After the last sandstone bed of the Medina stage had been deposited, the water probably became purer and deeper, and the 6 feet of Clinton shales were laid down in the Niagara region. In the eastern part of the Bay of New York, sandstones were deposited even during the Clinton epoch, while the conditions favoring the deposition of limestone existed only during the short interval in

the Niagara period, when the Coralline limestone of Schoharie was laid down. Westward, however, the adjustment of conditions went on more rapidly, and the Clinton limestones, with the calcareous shales and limestones of the upper Niagaran, became the characteristic deposits. During nearly the entire Niagara period life was abundant in the Siluric sea, and the Bay of New York had its marvelous succession of faunas, which have made these strata the standard for the Siluric beds of this continent.

All the Siluric limestones of the Niagara section show characters pointing to a fragmental origin, and in this respect they contrast strongly with the Devonic limestones in the southern part of the district. The latter, as before mentioned, show the characteristics of an ancient coral reef, and we may therefore assume that they were built up in situ by the polyps and other lime-secreting organisms. Not so with the Siluric limestones. These, to be sure, were derived from similar deposits by lime-secreting organisms, but these deposits were originally made in a different place from that in which we find the limestones today. A sedimentary limestone or lime-sandstone is similar to a quartz sandstone or a shale, in that the material of which it is formed is the product of erosion of preexisting rocks. In the case of the quartz sandstone, this is generally an inorganically formed rock, while the sedimentary limestones are most usually derived from organically formed rocks. In the former case, the source of the material is often a distant one, while in the latter it is generally, though not necessarily always, close at hand. A coral reef growing in moderately shallow water is attacked by the waves, as are all rocks which come within their reach. Erosion results, and the product of this activity is carried away and deposited on the ocean floor as a calcareous sand. Thus stratified deposits of limestones are formed, whereas in the original organic reef, no stratification is to be expected. In the immediate neighborhood of the growing reef, the beds of calcareous sand will slowly envelop the original deposit from which they were derived, and thus the source of supply is chiefly the upper growing portion of the reef. On the lime-sandstone strata which flank the reef, independent masses of coral may at times grow, while other or-

ganisms, such as mollusks and brachiopods, will also find this a convenient resting place. Thus the organically formed limestone masses and the fragmental limestones will interlock and overlap each other around the borders of a growing reef. It follows then that in the neighborhood of the growing coral masses the sands derived from their destruction will be coarser, the finer material being carried farther out to sea, and deposited at a distance from the source. Thus an approximate criterion for the determination of the distance of any given bed of calcareous sand from its place of origin is furnished. If deposits of such calcareous sand are made in shallow water, cross-bedding and ripple marks will be found just as in the quartz sands, and, as we have seen, the former structure is characteristic of most of the strata of Lockport limestone exposed in the gorge section at Niagara. It may be added that, as the organic limestone will continue to form as long as the conditions are favorable, the supply of calcareous sand is practically inexhaustible. Hence thick beds of such lime-sandstones may form.

In the Niagaran seas the chief reef-building corals were Favosites, Halysites and Heliolites, together with the hydro-coralline Stromatopora. Bryozoans also added largely to the supply of organically formed limestone of the various reefs. But perhaps the most important contributors in this connection were the crinoids and related organisms, which may at times have constituted reefs of their own. Their abundance is testified to by the frequent thick beds of limestone, which are almost wholly made up of broken and worn crinoid fragments. The crinoids fell an easy prey to the waves, for, on the death of the animal, the calyx, arms and stem would quickly fall apart into their component sections, and hence yield fragments readily transported by the waves. In the case of the corals and the shells, which latter probably formed no unimportant part of the organic contributions to the reefs, the work of grinding the solid limestone masses into a sand probably required the aid of tools, such as large blocks that could be rolled about by the waves, or it may have been aided by the omnipresent reef-destroying organisms.

The infrequency of exposure of the fossil reefs, which furnished the calcareous sand, need not disturb us. We must remember that

the actually exposed sections of these limestone strata are very few when compared with the great extent of the beds themselves. It must also be borne in mind, that vast portions of these limestone beds have been removed by erosion during the long post-Siluric time. When we realize that the actual reefs must have been widely scattered in the Niagara sea, and that our sections through these strata are random sections, we need feel no surprise at the unsatisfactory character of these exposures. It must however be added that sections farther east, as at Lockport or other localities, generally show much more of the reef character of the deposit, the corals in these being correspondingly abundant. The upper geodiferous beds of the limestone at Niagara were probably much more fossiliferous than the lower. As before mentioned, the geode cavities most likely are the result of alteration or solution of some fossil body, probably a coral. Though fossils may have been plentiful, none of these beds, so far as examined, show the characteristics of true reefs. They have more the aspect of beds of coral sand, on which isolated heads of corals and other organisms grew rather plentifully.

During the dolomitization of these limestone beds, which was probably brought about by chemical substitution before the consolidation of the coral sand, many of the fossils which were included in these sands probably suffered alteration and more or less complete destruction. Thus it will be seen that even the few organisms which were embedded in these coral sands, did not survive the subsequent changes, and thus the barrenness of these great limestone masses appears to be fully accounted for. The fossiliferous character of the upper Clinton limestone, as well as the coarseness of the calcareous fragments of which it is composed, points to a nearness of this rock to the source of the material; for in the vicinity of the coral and crinoid reefs the food supply for other organisms would be most abundant, and hence these would develop most prolifically in such a neighborhood.

A careful comparative study of the Niagaran deposits of New York and those of the middle states has brought out some important and interesting facts. These may be summed up in the

statement, that the New York fauna is more individualized, showing characteristics stamping it in some degree as a provincial fauna. The Niagaran fauna of the central states however is more closely allied to the European Mid-Siluric fauna than to that of New York state, from which we may conclude that the pathway of communication between the American and European Siluric seas was not by way of New York, a conclusion which is in entire harmony with those derived from the physical development of this region and the characteristics of the strata.

Weller[1] has collected data which indicate that the pathway of migration of faunas between the two continents was by way of the arctic region. According to Weller's interpretation of the facts, there existed in North America during Siluric time ". . . a north polar sea with a great tongue stretching southward through Hudson bay to about latitude 33°. There were doubtless islands standing above sealevel within this great epicontinental sea; and at the latitude of New York there was a bay reaching to the eastward, in which the Siluric sediments of the New York system were deposited. Labrador, Greenland and Scandinavia were in a measure joined into one great land area, though perhaps with its continuity broken, with a sea shelf lying to the north of it and another to the south. Another epicontinental tongue of this northern sea extended south into Europe, bending to the west around the southern part of the Scandinavian land and connecting with a Silurian Atlantic ocean. The sea shelf to the north of the Labrador-Scandinavian land was a means of intercommunication between northern Europe and the interior of North America, and the sea shelf to the south of this land was a pathway between England and eastern Canada." That portion of North America lying to the west of a line drawn from the Mississippi to the Mackenzie appears to have been dry land during the Niagara period, and connected with the Appalachian land on the east by the westward trending axis of the latter in the southern United States.

At the close of the Niagara period, there appears to have been an elevation of the continent which converted the Bay of New York

[1] Nat. hist. sur. Chicago acad. sci. bul. 4 and Jour. geol. 4:692-703.

and the greater part of the interior Siluric sea into a vast partially or entirely inclosed basin. This elevation appears to have been accompanied by climatic desiccation which brought about a rapid evaporation of the waters and a consequent increase in salinity. Thus this great interior water body was changed from a richly peopled mediterranean, to a lifeless body of intensely saline water, a veritable Dead sea. As the concentration of the brine continued, deposition of gypsum began, and later on the extensive beds of rock salt of this formation were laid down. Some of these salt beds in Michigan are reported to be a thousand feet thick, but none of the New York beds approach this thickness. The clastic strata of the Salina series were probably derived from the destruction of the sediments which were formed during the early periods of the Siluric and during preceding periods. This would account for the presence of limestone beds in deposits formed in a lifeless sea. All these limestones were more or less mixed with clayey sediments; they may in fact be regarded as consolidated argillo-calcareous muds derived from older limestones and shales. This is the character of the Waterlime and Manlius limestone which succeed the Salina beds, and which, though fossiliferous, could have no other source of origin than preexisting limestone beds.

The Waterlime has been regarded as a fresh-water formation. It is more likely however that it represents a return of marine conditions through the opening of channels between this interior basin and the ocean at large. This is indicated by the fauna, which includes undoubted marine forms. Whether this connection was through the old northern channel, or whether a new channel toward the east was opened is not apparent. The former is indicated by the character of the Manlius limestone which succeeds the Waterlime, and which in the Niagara region has features associating it with the corresponding deposits of Ohio, Michigan and Ontario, rather than its eastern equivalents. Whatever the nature of the transgression of the sea which took place in the late Siluric, it was not of long duration. The epoch of the Manlius limestone and with it the Siluric era were brought to a close with the withdrawal of all the waters from this portion of the continent, which thereafter for

a long period of time remained above the sea. During this time, the Helderbergian and other Lower Devonic strata were deposited in the Appalachian region, which by that time had established a southern connection with the open Atlantic.

Finally, toward the middle of the Devonic era, the sea once more transgressed on the abandoned continent, and again all this region was covered by oceanic waters. On the land surface of early Devonic times, now grew corals in great luxuriance; and reefs of great extent, with their accompanying deposits of coral sands, and their wealth of new life, again characterized the interior Paleozoic sea. It was not till long ages after, that this portion of the continent was again raised above the sea. This last elevation, which took place toward the close of Paleozoic time, was a permanent one, with the exception of a possible slight resubmergence of some parts of this region after the close of the glacial period. With the last great emergence of the land were inaugurated those long cycles of erosion outlined in chapter 1, which resulted in the formation of the great topographic features of this region, and which came to a close only with the envelopment of this region in the snow and ice of the great glacial winter.

APPENDIX

Partial bibliography of the geology of Niagara and the Great lakes

Ashburner, C. A. The geology of Buffalo as related to natural gas in New York state. Am. inst. min. eng. Trans. 16:1-54. 1888.

Bakewell, R. Observations on the falls of Niagara, with references to the changes which have taken place, and are now in progress. Am. jour. sci. 2d ser. 23:85-95. 1857.

——— Observations on the whirlpool and the rapids below the falls of Niagara; designed by illustrations to account for the origin of both. Am. jour. sci. 2d ser. 4:25-36. 1847.

Ballou, H. W. Niagara river. Scientific Am. sup. 13:5045-46. 1882.

Bishop, I. P. Salt wells of western New York. 5th an. rep't N. Y. state geologist. p. 12-47. 1886.

——— Structural and economic geology of Erie county [N. Y.]. 15th an. rep't N. Y. state geologist. 1:17-18, 305-92, pl. 1-16, fig. 1-6; 49th an. rep't N. Y. state mus. 2:305-92, pl. 1-16, fig. 1-6. 1898.

Chalmers, Robert. Pleistocene marine shore lines on the south side of the St Lawrence valley. Am. jour. sci. 4th ser. 1:302-8. 1896.

Clarke, J. M. The Oriskany Fauna of Becraft mountain. N. Y. state mus. Mem. 3. p. 95-103.

Claypole, E. W. Pre-glacial formations of the beds of the great American lakes. Can. nat. n. s. 9:213-27. 1881.

——— Evidence from the drift of Ohio, Indiana and Illinois in support of the pre-glacial origin of the basins of Lakes Erie and Ontario. Am. ass'n adv. sci. Proc. 30:147-59. 1882.

——— Eccentricity theory of glacial cold versus the fact. Edinburgh geol. soc. Trans. 5:534-48. 1885.

——— The old gorge at Niagara. Science. 8:236. 1886.

——— Buffalo and Chicago or "What might have been." Am. nat. 20:856-62; 1886. Am. ass'n adv. sci. Proc. 35:224. 1887.

——— On the pre-glacial geography of the region of the great lakes. Can. nat. n. s. 8:187-206. 1887.

——— Falls of rock at Niagara. Nature. 39:367. 1889.

Coleman, Arthur P. Glacial and interglacial deposits at Toronto (Canada). Brit. ass'n adv. sci. Rep't 1897. p. 650, 651.

——— Lake Iroquois and its predecessors at Toronto (Canada). Abstracts, Geol. soc. Am. Bul. 10:165-76; Am. geol. 33:103-4; Science. n. s. 9:143, 144.

Davis, William Morris. Was Lake Iroquois an arm of the sea? Am. geol. 7:139-41. 1891.

——— The ancient outlet of Lake Michigan. Pop. sci. mo. 46:217-29. 1895.

——— [Review of "Origin of the gorges of the whirlpool rapids at Niagara" by F. B. Taylor]. Science. n. s. 7:627. 1898.

——— Ancient coastal plain of western New York. Textbook of physical geography. p. 137, 138, fig. 86. 1899.

Dawson, George M. Inter-glacial climatic conditions. Am. geol. 16:65, 66. 1895.

Desor, E. Note sur l'existence de coquilles marines des mers actuelles dans le bassin du Lac Ontario (Canada) jusqu' a l'altitude de 310 pieds. Soc. geol. France. Bul. 2d ser. 8:420-23. 1851.

——— On the ridge road from Rochester to Lewiston, and on other similar terraces. Bost. soc. nat. hist. Proc. 3:358-59. 1851.

——— Ueber Niagara falls. Deutsche Geologische Gesellschaft, Zeitschrift. 5:643-44. 1853.

——— The falls of Niagara. Pottsville sci. ass'n. Bul. p. 5-10. 1855.

Fairchild, H. L. Glacial lakes of western New York. Geol. soc. Am. Bul. 6:353-74, pl. 18-23. 1895.

——— Lake Newberry the probable successor of Lake Warren. Abstract, Geol. soc. Am. Bul. 6:462-66. 1895.

——— Glacial Genesee lakes. Geol. soc. Am. Bul. 7:423-52, pl. 19-21. 1896.

——— Glacial geology of western New York. Geol. mag. Dec. 4. 4:529-37; Brit. ass'n adv. sci. Rep't 1897. p. 664.

——— Lake Warren shore lines in western New York and the Geneva beach. Geol. soc. Am. Bul. 8:269-84, pl. 30. 1897.

——— Glacial lakes Newberry, Warren and Dana in central New York. Am. jour. sci. 4th ser. 7:249-63, fig. 1, pl. 6. 1899.

Featherstonhaugh, G. W. On the ancient drainage of North America and the origin of the cataract of Niagara. Am. jour. of geol. and nat. sci. 1:13-21. 1831.

Fleming, Mary A. Pot holes of Foster's flats (now called Niagara glen) on the Niagara river. Abstract, Am. ass'n adv. sci. Proc. 48:226, 227; Science. n. s. 10:489. 1899.

Foerste, Aug. F. On Clinton conglomerates and wave marks in Ohio and Kentucky. With a résumé of our knowledge of similar occurrences in other Silurian strata of these states, and their evidence upon probable land conditions. Jour. of geol. 3:50-60, 169-97. 1895.

——— Account of the Middle Silurian rocks of Ohio and Indiana, including the Niagara and Ohio Clinton, and the bed at the top of the Lower Silurian strata, formerly considered the Medina. Cin. soc. nat. hist. Jour. 18:161-99. 1896.

——— Report on the Niagara limestone quarries of Decatur, Franklin and Fayette counties, with remarks on the geology of the Middle and Upper Silurian of these and neighboring counties of Indiana. Ind. dep't geol. and nat. res. 22d an. rep't. p. 195-255, pl. 14-18. 1898.

Foot, Lyman. Notices of geology and mineralogy (of Niagara falls region). Am. jour. sci. 4:35-37. 1822.

Gebhard, John. Observations on the geological features of the south side of the Ontario valley. Albany institute. Trans. 1:55-59. 1830; Am. jour. sci. 11:213-18. 1826.

Geer, Gerard de. On Pleistocene changes of level in eastern North America. Am. geol. 11:22-44; Bost. soc. nat. hist. Proc. 25:454-77. 1893.

Gibbes, L. R. Remarks on Niagara falls. Am. ass'n adv. sci. Proc. v. 10, pt 2, p. 69-78. 1857.

——— On some points which have been overlooked on the past and present condition of Niagara falls. Elliott soc. nat. hist. Proc. (S. C.) 1:91-100. 1859.

Gilbert, G. K. Old shore lines of Lake Ontario. Science. 6:222. 1885.

——— On a prehistoric hearth under the Quaternary deposits in western New York. Sci. Am. sup. 23:9221-22. 1887.

——— The place of Niagara falls in geological history. Am. ass'n adv. sci. Proc. 35:222-24. 1887.

——— Old shore lines in the Ontario basin. Can. inst. Proc. 3d ser. 6:2-4. 1888.

——— Changes of level of the Great lakes. Forum. 5:417-28. 1888.

——— History of Niagara river. 6th an. rep't. N. Y. state com. res. at Niagara. p. 61-84, 7 plates. 1890.

——— Discussion of the papers "Relationship of the glacial lakes Warren, Algonquin, Iroquois and Hudson-Champlain," and the two papers by J. W. Spencer, "The Iroquois shore north of the Adirondacks" and "Channels over divides not evidence per se of glacial lakes". Geol. soc. Am. Bul. 3:492-94. 1892.

———Itinerary, Chicago to Niagara falls. Int. cong. geol., Compte Rendu, 5th session. p. 453-58. 1894.

——— Old tracks of Erian drainage in western New York. Abstract. Geol. soc. Am. Bul. 8:285-86. 1897.

——— Recent earth movements in the Great lakes region. U. S. geol. sur. 18th an. rep't. pt 2, p. 601-47, pl. 105, fig. 93-101. 1898; Nat. geog. mag. 8:233-47, fig. 1-7. 1897; Abstract, Nature. 57:211-13, fig. 1. 1897; Am. geol. 23:126, 127; Am. jour. sci. 4th ser. 7:239-41; 15th an. rep't com. state res. at Niagara. p. 69-138, fig. 93-101. 1899.

——— Ripple marks and cross bedding. Geol. soc. Am. Bul. 10:135, 140, pl. 13, fig. 5; Abstract, Am. geol. 23:102; Science. n. s. 9:138. 1899.

——— Glacial sculpture in western New York. Geol. soc. Am. Bul. 10:121-30; Abstract, Am. geol. 23:103; Science. n. s. 9:143. 1899.

——— Niagara falls and their history. Nat. geog. Monog. v. 1, no. 7. 1895.

Gordon, C. H. [Review of "Correlation of Erie-Huron beaches with outlets and moraines in southeastern Michigan" by F. B. Taylor]. Jour. geol. 5:313-17. 1897.

Grabau, A. W. Siluro-Devonic contact in Erie county, New York. Geol. soc. Am. Bul. 11:347-76, pl. 21-22. 1900.

Grant, C. C. Geological notes. Hamilton ass'n. Jour. and proc. no. 12, p. 140-45. 1896.

Grote, A. R. & Pitt, W. H. New specimens from the Waterlime group at Buffalo, N. Y. Am. ass'n adv. sci. Proc. 26:300-2. 1878.

Gunning, W. D. Past and future of Niagara. Pop. sci. mo. 1:564-73. 1872.

Hall, James. Niagara falls, their physical changes and the geology and topography of the surrounding country. Bost. jour. nat hist. 4:106-34. 1834.

——— Geology of New York. Pt 4, Fourth geological district. Albany. 1843.

——— Glaciated surfaces of cherty limestone from near Niagara. Am. jour. sci. 45:332. 1843.

——— On the geology of the region of Niagara falls. Bost. soc. nat. hist. Proc. 1:52. 1844.

——— Paleontology of New York, v. 2. Organic remains of lower middle division of the New York system. Albany. 1852.

——— Note (on recession of Niagara falls). Am. ass'n adv. sci. Proc. v. 10, pt 2, p. 76-79. 1857.

——— (Description of Siluric formations of New York). Fossils of the Waterlime group. Pal. N. Y. 3:20-32, 282-424. 1859.

———On the relations of the middle and upper Silurian (Clinton, Niagara and Helderberg) rocks of the United States. Geol. mag. 9:509-13. 1872.

——— On the relations of the Niagara and Lower Helderberg formations, and their geographical distribution in the United States and Canada. Am. ass'n adv. sci. Proc. v. 22, pt 2, p. 321-35. 1874.

——— Descriptions of fossil corals from the Niagara and Upper Helderberg groups. 35th an. rep't N. Y. state mus. nat. hist. p. 407-64. pl. 23-30. 1884.

——— Niagara falls, its past, present and prospective condition. Rep't 4th geol. dist. N. Y. p. 383-404. 1842; 8th an. rep't com. state res. at Niagara. p. 67-89. 1892.

Hallett, P. Notes on Niagara. British ass'n. Rep't of 54th meeting. p. 744-45. 1885.

Hitchcock, C. H. The story of Niagara. Am. antiquarian. 23:1-24, 12 fig. Jan. 1901.

Holley, George W. Niagara, its history, geology, incidents and poetry. New York. 1872.

——— The proximate future of Niagara, in review of Professor Tyndall's lecture thereon. Am. ass'n adv. sci. Proc. v. 22, pt 2, p. 147-55. 1874; Abstract, Can. nat. n. s. 7:164-65. 1875.

Hovey, Horace C. Niagara river, gorge and falls. Sci. Am. sup. v. 22, no. 558, p. 897. 1886.

Hyatt, Alpheus. Rock ruins (Niagara falls). Am. nat. 2:77-85. 1869.

Leverett, Frank. On the correlation of New York moraines with raised beaches of Lake Erie. Am. jour. sci. 3d ser. 1:1-20. 1895.

——— Pre-glacial valleys of the Mississippi and tributaries. Jour. of geol. 3:740-63. 1895.

——— The Pleistocene features and deposits of the Chicago area. Chicago acad. sci. Bul. no. 2, 86p., pl. 1-4, fig. 1-8. 1897.

——— Correlation of moraines with beaches on the border of Lake Erie. Am. geol. 21:195-99. 1898.

Lesley, Joseph P. On the glacial erosion and outlets of the Great lakes. Am. phil. soc. Proc. 20:95-101. 1883.

Lyell, Charles. Niagara falls. Travels in North America, v. 1, ch. 2, p. 22-43. 1845.

Marcou, Jules. Le Niagara quinze ans apres. Soc. géol. France. Bul. 2d ser. 22:290-300, 529-30. 1865.

Maw, George. Geological history of the North American lake region. Geol. mag. n. s. 5:455-56. 1878.

Merrill, F. J. H. A guide to the study of the collections of the New York state museum. N. Y. state mus. Bul. no. 19, p. 107-262. 1898.

Mudge, E. H. Central Michigan and the post-glacial submergence. Am. jour. sci. 3d ser. 1:442-45. 1895.

Newberry, John S. Notes on the surface geology of the basins of the Great lakes. Bost. soc. nat. hist. Proc. 9:42-46. 1865.

——— On the surface geology of the basins of the Great lakes and the valley of the Mississippi. N. Y. lyceum nat. hist. Annals. 9:213-34. 1870; Am. nat. 4:193-218. 1871.

——— On the structures and origin of the Great lakes. N. Y. lyceum nat. hist. Proc. 2d ser. p. 136-38. 1874.

——— On the origin and drainage of the basins of the Great lakes. Am. phil. soc. Proc. 20:91-95.

——— History of the great American lakes. Abstract, Sci. Am. sup. 28:11,505-6; Eng. and min. jour. 48:201-2. 1889.

Nicholson, H. Alleyne. On the Guelph limestones of North America and their organic remains. Geol. mag. n. s. 2:343-48. 1875.

Pohlman, Julius. Cement rock and gypsum deposits in Buffalo. Am. inst. min. eng. Trans. Buffalo meeting 1888.

——— Life history of Niagara. Am. inst. min. eng. Trans. Buffalo meeting p. 1-17.

——— Thickness of the Onondaga salt group at Buffalo, N. Y. Buffalo soc. nat. sci. Bul. v. 5, no. 1, p. 97, 98. 1886.

——— Niagara gorge. Am. ass'n adv. sci. Proc. 35:221. 1887.

——— Life history of the Niagara river. Am. ass'n adv. sci. Proc. 32:202 1884.

——— Fossils from the Waterlime group at Buffalo, N. Y. Buffalo soc. nat. sci. Bul. v. 5, no. 1, p. 97, 98. 1886.

——— On certain fossils of the Waterlime group near Buffalo. Buffalo soc. nat. sci. Bul. v. 4, no. 1, p. 17-22. 1882.

——— Additional notes on the fauna of the Waterlime group near Buffalo. Buffalo soc. nat. sci. Bul. v. 4, no. 2, p. 41-46. 1882.

Quereau, Edmund Chase. Topography and history of Jamesville lake, New York. Geol. soc. Am. Bul. 9:173-82, pl. 12-14. 1898.

Ringueberg, E. N. S. The crinoidea of the lower Niagara limestone at Lockport, N. Y. with new species. N. Y. acad. sci. An. 5:301-6, pl. 3. 1891.

Ringueberg, E. N. S. Evolution of forms from the Clinton to the Niagara group. Am. nat. 16:711-15. fig. a-e. 1887.

——— Niagara shales of western New York; a study of the origin of their subdivisions and their faunae. Am. geol. 1:264-72. 1888.

——— New genera and species of fossils from the Niagara shales. Buffalo soc. nat. sci. Bul. v. 5, no. 2, p. 5-21, pl. 1, 2. 1886.

Rogers, Henry D. On the falls of Niagara, and the reasonings of some authors respecting them. Am. jour. sci. 27:326-35. 1835.

Russell, Israel Cook. Geography of the Laurentian basin. Am. geog. soc. Bul. 30:226-54. 6 fig. 1898.

Schmidt, Friedrich. Eurypterus beds of the Oesel as compared with those of North America. Geol. soc. Am. Bul. 3:59. 60. 1892.

Scovell, J. T. An old channel of the Niagara river. Am. ass'n adv. sci. Proc. 39:245. 1891.

Shaler, N. S. Geology of Niagara. The Niagara book. Buffalo N. Y.

Spencer, J. W. Short study of the features of the region of the lower Great lakes during the Great river age; or, Notes on the origin of the Great lakes of North America. Am. ass'n adv. sci. Proc. 30:131-46. 1882.

——— Discovery of the pre-glacial outlet of the basin of Lake Erie into that of Lake Ontario, with notes on the origin of our lower Great lakes. Am. phil. soc. Proc. 24:409-16, pl. 6, 7. 1882; 2d geol. sur. Pa. Rep't Q 4, p. 357-404.

——— Traces of beaches about Lake Ontario. Am. jour. sci. 24:409-16, pl. 6, 7. 1882.

——— Paleozoic and surface geology of the region about the western end of Lake Ontario. Can. nat. n. s. 10:129-71, 213-36, 265-312. 1883.

——— Terraces and beaches about Lake Ontario. Am. ass'n adv. sci. Proc. 31:359-63. 1883.

——— Age of the Niagara river. Am. nat. 21:269-70. 1887.

——— The Iroquois beach, a chapter in the history of Lake Ontario. Abstract. Science. 11:49. 1888.

——— The St Lawrence basin and the Great lakes. Abstract, Can. rec. of sci. 3:232-35. 1888; Science. 12:99-100. 1888; Sci. Am. sup. 26:10,671-72. 1888; Am. geol. 2:346-48. 1888; Am. ass'n adv. sci. Proc. 37:197-99. 1889; Am. nat. 23:491-94. 1889.

——— Notes on the origin of the Great lakes of North America. Am. ass'n adv. sci. Proc. 37:197, 198. 1889.

——— The Iroquois beach; a chapter in the geological history of Lake Ontario. Roy. soc. Can. Trans. v. 7, §4, p. 121-24. 1890; Abstract, Am. nat. 24:957; Am. geol. 6:311-12. 1890.

——— The deformation of the Iroquois beach and birth of Lake Ontario. Am. jour. sci. 40:443-52. 1890.

——— The northwestern extension of the Iroquois beach in New York. Am. geol. 6:294. 295. 1890.

——— Deformation of the Algonquin beach, and birth of Lake Huron. Am. jour. sci. 3d ser. 41:12-21. 1891.

Spencer, J. W. High-level shores in the region of the Great lakes and their deformation. Am. jour. sci. 41:201-12. 1891.

——— Prof. W. M. Davis on the Iroquois beach. Am. geol. 7:68, 266. 1891.

——— Origin of the basins of the Great lakes of America. Am. geol. 7:86-97. 1891.

——— Channels over divides not evidence per se of glacial lakes. Geol. soc. Am. Bul. 3:491-92; Abstract. Am. geol. 11:58. 1892.

——— Review of the history of the Great lakes. Am. geol. 14:289-301, pl. 8. 1894.

——— Drainage of the Great lakes in the Mississippi by way of Chicago. Abstract. Am. nat. 28:884. 1894.

——— Deformation of the Lundy Beach and birth of Lake Erie. Am. jour. sci. 3d ser. 47:207-12. 1894.

——— Niagara falls as a chronometer of geological time. Abstract, Roy. soc. London. Proc. 1:145-48. 1894.

——— Age of Niagara falls. Am. geol. 14:135, 136. 1894.

——— Duration of Niagara falls. Am. jour. sci. 3d ser. 48:455-72; Abstract. Am. geol. 14:204 (7l.); Abstract. Am. nat. 28:859-62. 1894.

——— [Lake Newberry as the probable successor of Lake Warren]. Geol. soc. Am. Bul. 6:466. 1895.

——— Duration of Niagara falls. Abstract. Am. ass'n adv. sci. 43:244-46. 1895.

——— Geological survey of the Great lakes. Am. ass'n adv. sci. Proc. 43:237-43. 1895.

——— Niagara as a time piece. Pop. sci. mo. 49:1-19, fig. 1-17. 1896.

——— How the Great lakes were built. Pop. sci. mo. 49:157-72, fig. 1-15. 1896.

——— On the continental elevation of the glacial epoch. Brit. ass'n adv. sci. Rep't 1897. p. 661, 662. 1898.

——— On Mr Frank Leverett's "Correlation of moraines with beaches on the border of Lake Erie." Am. geol. 21:393-96, fig. 1. 1898.

——— Another episode in the history of Niagara river. Abstract, Am. ass'n adv. sci. Proc. 47:299; Science. n. s. 8:501, 502; Am. geol. 22:259-60; Am. jour. sci. 4th ser. 6:439-50, 2 fig. 1898.

——— Niagara as a time piece. Can. inst. Proc. n. s. 1:101-3. 1898.

Stose, George W. A specimen of Ceratiocaris acuminata Hall from the Waterlime of Buffalo, N. Y. Bost. soc. nat. hist. Proc. 26:369-71. 1894.

Tarr, Ralph S. Physical geography of New York state. pt 7. The Great lakes and Niagara. Am. geog. soc. Bul. 31:101-17 (4 fig.), 217-35 (10 fig.), 315-43 (21 fig.) 1899.

Taylor, F. B. The highest old shore-line on Mackinac island. Am. jour. sci. 3d ser. 43:210-18; Abstract. Am. ass'n adv. sci. Proc. 40:260-61. 1892.

Taylor, F. B. The limit of post-Glacial submergence in the highlands east of Georgian Bay [Ontario]. Am. geol. 14:273-89, with map. 1894.

—— The ancient strait at Nipissing [Ontario]. Geol. soc. Am. Bul. 5:620-26, pl. 20; Abstract, Am. geol. 13:220-21. 1894.

—— A reconnaissance of the abandoned shore lines of Green bay [Michigan and Wisconsin]. Am. geol. 13:316-27, with a map. 1894.

—— A reconnaissance of the abandoned shore lines of the south coast of Lake Superior. Am. geol. 13:365-83, with map. 1894.

—— The Nippissing beach on the north Superior shore. Am. geol. 15:304-14. 1895.

—— Niagara and the Great lakes. Am. jour. sci. 3d ser. 49:249-70. 1895.

—— The Munuscong islands [Michigan]. Am. geol. 15:24-33. 1895.

—— The second Lake Algonquin. Am. geol. 15:100-20 and 162-79. 1895.

—— Changes of level in the region of the Great lakes in recent geological time. [Letter to J. D. Dana] Am. jour. sci. 3d ser. 49:69-71. 1895.

—— [On the use of the term " Erigan "]. Am. geol. 15:394-95. 1895.

—— Preliminary notes on studies of the Great lakes made in 1895. Am. geol. 17:253-57. 1896.

—— The Algonquin and Nipissing beaches. Am. geol. 17:397-400. 1896.

—— Notes on the Quaternary geology of the Mattawa and Ottawa valleys [Ontario]. Am. geol. 18:108-20. 1896.

—— Correlation of Erie Huron beaches with outlets and moraines in southeastern Michigan. Geol. soc. Am. Bul. 8:31-58. pl. 2. 1897.

—— Scoured boulders of the Mattawa valley [Ontario]. Am. jour. sci. 4th ser. 3:208-18. 1897.

—— The Nipissing-Mattawa river the outlet of the Nipissing great lakes. Am. geol. 20:65-66. 1897.

—— Short history of the Great lakes. Studies in Indiana geography, ed. by C. R. Dryer. 1:90-110, fig. 1-4. 1897.

—— The Champlain submergence and uplift. and their relation to the Great lakes and Niagara falls. Brit. ass'n adv. sci. Rep't 1897. p. 652-53. 1898.

—— Origin of the gorge of the whirlpool rapids at Niagara. Geol. soc. Am. Bul. 9:59-84. fig. 1, 2. 1898.

—— The great ice dams of Lakes Maumee, Whittlesey and Warren. Am. geol. 24:6-38, pl. 2, 3. 1899.

Tyndall, John. Some observations on Niagara. Pop. sci. mo. 3:210-26. 1873.

Upham, Warren. Relationship of the Glacial lakes Warren, Algonquin, Iroquois and Hudson-Champlain. Abstract. Geol. soc. Am. Bul. 3:484-87; Abstract, Am. geol. 11:59. 1892.

—— The Champlain submergence. Abstract. Geol. soc. Am. Bul. 3:508-11; Abstract. Am. geol. 11:119. 1892.

Upham, Warren. The fjords and Great lakes basins of North America considered as evidence of pre-glacial continental elevation and of depression during the glacial period. Geol. soc. Am. Bul. 1:563-67. 1890.

—— Altitude as the cause of the glacial period. Science. 22:75, 76. 1893.

—— Estimates of geologic time. Am. jour. sci. 3d ser. 45:209-20; Sci. Am. sup. 35:14, 403-5. 1893.

—— Epeirogenic movements associated with glaciation. Am. jour. sci. 3d ser. 46:114-21. 1893.

—— Wave-like progress of an epeirogenic uplift. Jour. of geol. 2:383-95. 1894.

—— The Niagara gorge as a measure of the post-glacial period. Am. geol. 14:62-64. 1894.

—— Stages of recession of the North American ice sheet, shown by glacial lakes. Am. geol. 15:396-99. 1895.

—— Departure of the ice sheet from the Laurentian lakes. Abstract, Geol. soc. am. Bul. 6:21-27. 1895.

—— Late glacial or Champlain subsidence and reelevation of the St Lawrence river basin. Am. jour. sci. 3d ser. 49:1-18, with map. 1895; Minn. geol. and nat. hist. sur. 23d an. rep't, p. 156-93. 1895.

—— Beaches of Lakes Warren and Algonquin. Am. geol. 17:400-2. 1896.

—— Origin and age of the Laurentian lakes and of Niagara falls. Am. geol. 18:169-77, fig. 1. 1896.

—— Niagara gorge and Saint Davids channel. Geol. soc. Am. Bul. 9:101-10. 1898.

Walker, A. E. Hamilton sponges [Ontario]. Hamilton ass'n. Jour. and proc. no. 11, p. 85-87. 1895.

Weller, Stuart. The Silurian fauna interpreted on the epicontinental basis. Jour. geol. 6:692-703, 2 fig. 1898.

—— Paleontology of the Niagaran limestone in the Chicago area. The Crinoidea. Chicago acad. of sci. The natural history survey. . . Bul. 4. pt 1. 1900.

Westgate, Lewis G. Geographic development of the eastern part of the Mississippi drainage system. Am. geol. 11:245-60; Abstract, Jour. of geol. 1:420, 421. 1893.

Winchell, Alexander N. Age of the Great lakes of North America. Am. geol. 19:336-39. 1897.

Woodward, R. S. On the rate of recession of the Niagara falls, as shown by the results of a recent survey. Am. ass'n adv. sci. Proc. 35:222. 1886.

Worthen, A. H. Remarks on the relative age of the Niagara and so-called Lower Helderberg groups. Am. ass'n adv. sci. Proc. 19:172-75. 1870.

Wright, G. F. Niagara river and the glacial period. Am. jour. sci. 28:33-35. 1884.

—— The ice age in North America. Appleton. 1889.

Wright, G. F. The supposed post-glacial outlet of the Great lakes through Lake Nipissing and the Mattawa river. Geol. soc. Am. Bul. 4:423-25. 1893.

——— Age of Niagara falls as indicated by the erosion at the mouth of the gorge. Abstract, Am. ass'n adv. sci. Proc. 47:299-300; Abstract, Science. n. s. 8:502; Abstract, Am. geol. 22:260, 261. 1898.

——— New method of estimating the age of Niagara falls. Pop. sci. mo. 55:145-54, 6 fig. 1899.

——— Lateral erosion at the mouth of the Niagara gorge. Abstract, Science. n. s. 10:488. 1899.

Glossary

aberrant—differing from the type
acanthopores—hollow spines occurring between the apertures on the frond of a bryozoan
acinus—a berry
adductor muscles—closing muscles in bivalve shells
agglutinate—firmly united
air-chambers—chambers below the living chamber in the shells of cephalopods
alar—pertaining to wings; the lateral primary septa of the tetracoralla
alate—having wing-like expansions
ambulacral areas—perforated areas in the test of an echinoderm, through which the tubed feet project
anastomosing—uniting to form a net work
angulated—with angles or corners
ankylosed—firmly united; grown together
annulations—rings, or ring-like segments
annulus—a ring; a segment of the thorax of a trilobite
antennae—paired articulated appendages of head of arthropod—trilobite
anterior—front
aperture—opening of shells, cells, etc.
apex—terminal or first-formed portion of gastropod shells
apophysis—a calcareous process (in interior of shells, etc.)
appressed—pressed closely against
arcuate—arched; bent like a bow
articulated—joined by interlocking processes, or by teeth and sockets
asperate—rough
attenuated—tapering; or thinning
auricle—ear, or anterior projection of the hinge of many pelecypods
auriculate—eared
aviculoid—resembling Avicula, winged
axial canal—central canal of crinoid stem
axial furrows—furrows or depressions delimiting the axis in trilobites
axis—central longitudinal division of the body of a trilobite
azygous—unpaired; the azygous side of the calyx of a crinoid has plates differing from those of the regular sides

basals—lowest cycle or cycles (in forms with dicyclic base) of plates in the crinoidea
beak—area of the apex or initial point of a shell
biconvex—both valves convex, as in most brachiopods
bifid—split in two
bifoliate—two-leaved
bifurcating—dividing in two, forking

biserial—with double series or rows
brachial—pertaining to the brachia or arms of brachiopods or crinoids; one of the arm plates of crinoids
brachidium—calcareous support of the arms in brachiopods
branchiae—gills
bryozoum—whole compound colony of the bryozoa
bulbiform—bulb-shaped
byssal notch—notch or opening for the emission of the byssus (supporting-threads spun by the foot) in the pelecypoda

calicinal—pertaining to the calyx or cup
callosity—hardened spot or area
callus—thickened part of the inner lip of gastropods, which usually covers portions of the preceding volutions
calyx—1) cup of corals, limited below by the septa; 2) body, exclusive of the arms, of crinoids, cystoids and blastoids
camerate—chambered; an order of crinoidea
camerae—air-chambers of a cephalopod shell
canaliculate—channeled; having a canal
cancellated—marked by lines crossing each other; lattice-like
carapace—hard shell or shield of crustacea
cardinal—pertaining to the area of the beak in brachiopods and pelecypods
cardinal process—process from under the beak of the brachial valve of brachiopods, to which the diductor (opening) muscles are attached
cardinal quadrants—two quadrants of a Tetracorallum which bound the main, or cardinal, septum
cardinal septum—first or main of the four primary septa of a Tetracorallum; the cardinal septum has the pinnate arrangement of the secondary septa on both sides
cardinal teeth—teeth under the beak in the pelecypods; teeth in the pedicle valve of the brachiopods
carina—projecting ridge running down the center of the branches in some fenestelloid and other bryozoa; the projecting ridges on the septa of Heliophyllum and other corals
carinated—having a ridge or keel
cartilage—compressible, elastic substance between the hinge-margins of the valves of pelecypods. The cartilage is the internal, as the ligament is the external medium for opening the valves
cast—the impression taken from a mold
caudal—pertaining to the tail
celluliferous—cell bearing (bryozoa commonly have a celluliferous and a non-celluliferous side)
cephalic limb—anterior border of the cephalon of a trilobite
cephalon—head-shield of trilobites
cephalothorax—combined head and thorax of crustacea
cercopods—lateral tail spines in the ceratiocarida

cespitose—matted, tangled or growing in low tufts
cheeks—lateral portions of the cephalon, divided into fixed and free cheeks, of a trilobite
chelae—pincer-like claw terminating some of the legs of crustacea
chilidium—covering for the chilyrium
chilyrium—triangular opening under the beak of the brachial valve in those brachiopods in which that valve is furnished with a hinge-area
chitinous—composed of chitin, the substance forming the horny wings or elytra of beetles, and the carapaces of crustacea
cicatrix—a scar
cincture—depression anterior to the beak in the shell of some pelecypods
cirri—root-like appendages to the stem of crinoids
clastic—consisting of fragments, i. e. rocks made of fragments of older rocks
clavate—club-shaped
clavicle—heavy internal ridge running downward from the beak in some pelecypods
columella—central or axillary rod
compound corallum—made up of corallites, either separate or closely joined by their walls (ex. Favosites)
composite corallum—compound corallum with coenenchyma or extrathecal calcareous tissue connecting the corallites (ex. Galaxia and many other recent forms)
concavo-convex—shells of brachiopods are normally concavo-convex, when the brachial valve is concave, and the pedicle valve convex; reversed or resupinate, when the reverse condition obtains
confluent—blended so that the line of demarcation is not visible
coniferae—order of arborescent plants to which the pines, firs, etc. belong
consequent stream—type of stream which flows down the original constructional slope of the land
corallites—individual tubes of a compound corallum
corallum—calcareous skeleton of a single, or of a colonial, coral stock
corneous—horny
coronal—crown-like
costae—extrathecal extensions of the septa of the corals
costals—first brachial or arm-plates of the crinoids lying between the radials and the first bifurcation of the arms
counter quadrants—quadrants bounding the counter septum of a Tetracorallum
counter septum—front primary septum of the Tetracoralla, opposite the cardinal septum; the secondary septa are parallel to it
crenulated—notched to produce series of teeth
crura—apophyses to which the brachidium of the brachiopods is attached
cuesta—topographic relief element, resulting from the normal dissection of a coastal plain composed of alternating harder and softer strata (see p. 40)

cuneate—wedge-shaped
cuneiform—wedge-shaped
cyathophylloid—in form like Cyathophyllum; one of the Tetracoralla
cyst—a closed cavity
cystoid—most primitive class of Pelmatozoa or stemmed echinoderms

delthyrium—triangular fissure under the beak of the pedicle valve of the brachiopoda
deltidium—single covering plate of the delthyrium (also called pedicle plate)
deltidial plates—two plates which close the delthyrium in the higher brachiopoda (Telotremata)
dendroid—branching after the manner of a tree
dental plates—internal plates below the teeth in pedicle valve of the brachiopoda
denticles—small teeth, or tooth-like ridges
denticulate—toothed
denticulation—set of denticles or small teeth
depressed—on a level with, or below the general surface
dextral (right handed)—the normal method of coiling in the gastropoda
diaphragm—transverse partitioning plate
dicyclic—with two cycles of basals; applied to crinoids
diductor muscles—opening muscles of the brachiopoda
discinoid—resembling Discina
discoid—disk-like
dissepiments—partitions; the intrathecal connecting plates between the septa of the corals; the connecting bars between the branches of a fenestelloid bryozoum
distal—situated away from the center of the body
distichals—second series of arm plates or brachials of crinoids, situated above the axillary costals
divaricators—opening muscles of brachiopoda; also called diductors
dorsal—pertaining to the back
doublure—infolded margin of a trilobite

ear—anterior cardinal expansion of the pelecypod shell, usually smaller and more distinctly defined than the posterior expansion or wing
echinate—spinous
endoderm—inner cellular body layer
emarginate—with a notched margin
endoderm—inner cellular body layer
endothecal—within the theca; intrathecal; used for corals
epicontinental—encroaching on the continent
epidermal—pertaining to the skin
epitheca—outer calcareous covering of a corallum or bryozoum
equilateral—with similar sides
equivalve—with similar valves
escharoides—like Eschara (a bryozoan)

escutcheon—depression behind the beak of the pelecypod shell
exfoliate—peeling off
exothecal—outside of the theca of corals
explanate—spread out in a flat surface
extrathecal—outside of the theca of corals
extroverted—turned base to base; applied to spirals of brachiopods

facetted—having facets or numerous faces as the eye of an insect, etc.
facial sutures—sutures in the cephalon of trilobites which separate the free from the fixed cheeks
facies—local characteristics
falcate—curved like a scythe or sickle
fasciculate—clustered
fathom—a measure of length equaling 6 feet used chiefly for depths of the sea
fenestrule—open spaces between the branches and dissepiments of a fenestella frond
filament—a fine thread or fiber
fimbriae—a fringe
fixed cheek—that part of the cephalon of a trilobite which lies between the glabella and the facial suture
fission—the act of splitting or cleaving into parts
flabellate—fan-shaped
flange—a projecting rim
flexibilia—an order of crinoids characterized by the loose jointing of the plates of the calyx
fold—the central elevation of the valve, usually the brachial of a brachiopod
foliate—leaf-like; in the form of a thin leaf-like expansion
foramen—an opening or pore; specifically the opening for the pedicle in the pedicle valve of the brachiopoda
fossula—groove in the calyx of a coral, usually due to the abortion of a septum
free cheeks—lateral portions of the cephalon of trilobites separated off by the facial sutures
frond—foliaceous or leaf-like expansion of the skeleton of bryozoa and other organisms
fruticulose—resembling a small shrub
fucoid—a seaweed, particularly of the type similar to the modern Fucus, or rockweed

galeate—with a helmet-like covering
gastric—pertaining to the stomach
genal angles—posterior lateral angles of the free cheeks of trilobites
genal spines—posterior prolongations, or spines, of the free cheeks of trilobites
geode—a hollow concretion usually lined with crystals, but also filled completely with foreign mineral matter

geodiferous—containing or abounding in geodes
geodetic—geode-bearing, pertaining to geodes
gibbous—swollen or humped
glabella—central, most prominent portion of the trilobite cephalon, bounded by the fixed cheeks
glomerate—growing in dense heads or clusters, generally of an irregular character
gonopolyp—reproductive polyp of Hydrozoa
granulated—having small and even elevations resembling grains
granulose—bearing or resembling grains or granules

hexacoralla—class of corals built on the plan of six
hinge area—flat area bordering the hinge line of many brachiopods
hinge line—line of articulation
hydrocoralline—order of Hydrozoa which build calcareous skeletal structures
hydroid—animal belonging to the class of Hydrozoa
hydrotheca—cup inclosing the nutritive polyp in thecaphore Hydrozoa
hyponome—water tube, or squirting organ, of squids, cuttlefish, and other cephalopods
hypostoma—underlip of the trilobites, usually found detached

imbricate—overlapping serially
implantation—planting between, as a new plication suddenly appearing between two older ones
inarticulate—not articulating by teeth and sockets; of brachiopoda
incised—cut into
incrusting—covering as with a crust
inequilateral—having unequal sides
inface—steep face or escarpment of a cuesta, facing toward the old-land
inferior—lower in position
inflated—distended in every direction and hollow within
inflected—bent or turned inward or downward
infrabasals—lower cycle of basal plates in the crinoids with dicyclic base
infundibuliform—funnel-shaped
inosculating—connecting, so as to have intercommunication
interambulacral—between the ambulacra
interapertural—between the apertures
interbrachials—plates in the calyx of a crinoid, lying between the brachials
intercalation—irregular interposition
intercellular—between the cells or meshes
interdistichals—plates in the calyx of a crinoid, lying between the distichals
interradials—plates in the calyx of a crinoid, lying between the radials
interstitial—pertaining to an intervening space; between lines, plications, etc.
intervestibular—between the vestibules or circumscribed areas
interzooecial—between the zooecial tubes in bryozoa, etc.

intrathecal—within the theca; endothecal
introverted—turned apex to apex; applied to the spirals of brachiopods
involute—rolled up, as a Nautilus shell

joints—component segments of the stem of a crinoid
jugum—yoke-like connection between the two parts of the brachidium of a brachiopod

keel—strong central carina or ridge (Taeniopora)

lacrymiform—tear-form; drop shaped—pear shaped, but without the lateral contractions
lamellar—disposed in lamellae or layers
lamellibranch—leaf-gilled, the class of molluska with bivalved shell, to which the oyster and clam belong; pelecypod
lamelliform—having the form of a leaf or lamella
lamellose—made up of lamellae
lamina—a thin plate or scale
lateral gemmation—a budding from the sides, as in some corals
lateral teeth—ridge-like projections on either side of the beak, in the interior of lamellibranch shells
laviformia—primitive order of crinoids
ligament—external structure for opening the valves in the pelecypoda
limb—lateral area or marginal band of the cephalon of trilobites on either side of the glabella, corresponding to a pleuron of the thoracic region
lines of growth—lines marking the periodic increase in size, in shells
linguiform—tongue-shaped
linguloid—tongue-shaped; like Lingula
lip—margins of the aperture of univalve shell
listrium—depressed area surrounding the pedicle opening in the pedicle valve of Orbiculoidea and other discinoid brachiopods
lithic—pertaining to stone
living chamber—the last chamber in the shell of a cephalopod, which is occupied by the animal
lobes—backward bending portions of the suture of cephalopod shells
lophophore—ciliated or tentaculated, oral disk of bryozoa; the oral disk and brachia of brachiopods
lunarium—more or less thickened portion of the posterior wall of the cell in many paleozoic bryozoa, which is lunate or curved to a shorter radius, and usually projects above the plane of the cell aperture
lunule—depression in front of the beak of pelecypod shells

macerate—softening and disintegrating by immersion in water
macrocorallites—the larger corallites in a compound corallum
maculae—irregular, usually depressed, areas on the celluliferous face of a bryozoan frond, which are free from cells, or otherwise differentiated
mandibles—first upper or outer pair of jaws of crustacea and insects

mantle—fleshy membrane infolding the soft parts of mollusks and brachiopods and building the shell
medullary rays—the "silver grain" or radiating vertical bands or plates of parenchyma in the stems of exogenous plants
medusa—a jelly fish
membranaceous—pertaining to a membrane
mesial—central
mesogloea—central, non-cellular layer in the body of coelenterates
meso-pores—irregular meshes or cysts on the intercellular spaces of certain bryozoa
mesotheca—median wall separating opposed cells in certain bryozoan fronds
metastonia—underlip of crustacea, composed of small pieces immediately below and behind the mouth
microcorallites—smaller corallites of a compound corallum
mold—any impression of a fossil, in rock matrix, external or internal
moniliform—resembling a necklace or string of beads
monocyclic—of a single cycle
monticuliporoids—corals belonging to the order Monticuliporidae having many points of resemblance with the bryozoa
monticules—elevated areas on the surface of certain coral and bryozoan colonies, commonly carrying larger apertures
mucronate—produced into a long pointed extension
mural pores—pores in the walls of the corallites of the Favositidae
muscle scar—scar in a shell marking the former attachment of a muscle

nacreous—pearly; the nacreous layer of shells is the inner smooth pearly layer
nariform—shaped like a nostril
nasute—projecting, nose-like
nettlecell—one of the nematocysts or stinging cells found covering the tentacles and other body parts of most Coelenterata
node—knob; usually considered as ornamental
nodose—bearing nodes or tubercles
nodulose—knotty, or having nodes

obconical—inversely conical
oblate—flattened at the poles
obovate—inversely ovate or egg-shaped
obsequent stream—a stream flowing down the inface of a cuesta, or toward the old-land, tributary to the subsequent stream which in turn flows into the consequent
occipital—applied to the posterior part of the cephalon of a trilobite
occipital furrow—transverse groove on the cephalon of trilobites, which separates the last or occipital ring from the rest of the cephalon
occipital ring—posterior division of the glabella of a trilobite cephalon
operculiform—resembling an operculum
operculum—lid or cover

paddles—large or last pair of thoracic legs of the eurypterids

pallial line—line on the interior of the shell of mollusks marking the attachment of the mantle

pallial sinus—reentrant angle in the pallial line usually at the posterior end of the shell of pelecypods; it marks the attachment of the siphon muscles

palmars—third series of brachial plates of the Crinoidea, lying above the axillary distichals

palmate—palm-shaped

palpebral lobes—supra-orbital extensions from the fixed cheeks of trilobites

papilla—a small nipple-shaped protuberance

papillose—covered with papillae or fine projections

parabasals—second cycle of basal plates in crinoids

pectinated rhombs—paired pore clusters in the calyx of certain cystoids (Callocystites)

pedicle—fleshy peduncle or stem used for attachment in the brachiopoda

pedicle valve—valve which gives emission to the pedicle in the brachiopoda. Ventral of most authors. Usually the larger valve

pentameroid—five chambered, similar to Pentamerus

pentapetalous—resembling a five-petaled flower

penultimate—next to the last

periderm—outer chitinous covering of Hydrozoa

periostracum—epidermis or outer organic coating of shells

peripheral—pertaining to the circumference

peristome—margin of an aperture, i. e. the mouth of a univalve molluscan shell, the mouth of a bryozoan cell, etc.

peritheca—epitheca covering which surrounds a colony of corallites, i. e. a compound corallum

petaloid—resembling a leaf or petal

pinnate—shaped like a feather

pinnulate—provided with pinnules

pinnules—finest divisions of the arms of crinoids

plano-convex—normally in brachiopods, with the pedicle valve convex and the brachial valve flat

pleura—lateral portions of the thoracic rings of trilobites

plicate—plaited or folded

plications—folds or rib-like plaits of a brachiopod shell

polyp—animal of a simple coelenterate or bryozoan

polypite—individual polyp of a colony

pore-rhombs—pore clusters, arranged in rhombic manner in the calyx of cystoids

poriferous—pore-bearing, corals which like Favosites are furnished with several pores

posterior—situated behind

post-palmars—all the plates, superior to the axillary palmars in the arms of crinoids

prehensile—adapted for seizing

preoral—situated in front of the mouth

produced—drawn out, elongated

proliferous—reproducing buds from the calyx

protoconch—embryonic shell of a cephalous molluscan

proximal—nearest or basal portion

pseudocolumella—false columella in corals, formed by a twisting of the septa

pseudodeltidium—false deltidium (Spirifer), formed by union of the two deltidial plates

pseudosepta—septa-like ridges of Chaetetes, etc., the projecting ends of the lunaria in the cells of certain bryozoa

pseudotheca—false wall or theca in some corals, formed by the expansion of the outer margins of the septa

punctate—dotted, with scattered dots or pits

pustule—small blister-like elevation

pustulose—bearing pustules or projections

pygidium—posterior or tail portion of the carapace of trilobites

pyramidal—having the form of a pyramid

pyriform—pear-shaped

pyriformis—pear-shaped

quadrangular—four angled

quadrate—with four equal and parallel sides

quadrifid—cut into four points

quadrilobate—bearing four lobes

quadriplicate—with four folds

quincunx—five objects arranged in a square with one in the middle

rachis—central stem of a frond in bryozoa, etc.

radials—main plates of the calyx of a crinoid, resting on the parabasals, and alternating with them

radii—ribs or striations diverging from the beak of a shell

ramose—branching

ramus—branch of a skeletal structure

reniform—kidney form

resilium—internal cartilage or compressible substance in the hinge of pelecypods

reticulated—like a network

retractile—capable of being withdrawn

retral—backward

rhynchonelloid—resembling Rhynchonella

root—expanded basal portion of a crinoid stem, used for fixation

rostrum—a beak or snout

rugosa—an old name for the Tetracoralla

saddles—forward bending portions of the suture in the shells of cephalopods
salient—standing out prominently
scabrous—rough or harsh with little projecting points
scalae—small transverse plates in the genus Unitrypa of the bryozoa
scalariform—stair or ladder-shaped
sclerenchyma—calcareous tissue deposited by the coral polyps
scorpioid—scorpion-like, coiled like the tail of a scorpion
semilunar—crescentic, or resembling a half moon
semiovate—half egg-shaped
senile—pertaining to old age
septal radii—radiating ridges taking the place of septa in certain corals
septate—with partitions or septa
septum—partition; in corals, the radiating calcareous plates; in cephalopods, the transverse partitions between the chambers
serrate—notched like a saw
setiferous—bristle-bearing
sigmoid—curved like the Greek letter Σ (sigma)
sinistral—left handed, reversed coiling of some gastropod shells
sinuate—wavy, winding
sinuosity—notch or incision forming a wavy outline
sinus—impression in the surface or margin of a shell
siphonal funnel—siphonal projection from the septum of a cephalopod shell
siphonal lobe—lobe in the suture of an ammonoid shell, corresponding in position to the siphuncle
siphuncle—tubular canal passing through the air chambers in the shells of cephalopods
slickensides—polished or striated surfaces on rock due to motion under great pressure
sockets—hollows in the brachial valve of brachiopods for the reception of the teeth of the opposite valve
spatulate—shaped like a spatula; spoon-shaped
spheroidal—globose, of the form of a spheroid
spiniform—spine-like
spinulose—spine bearing
spondylium—spoon-shaped cavity under the beak of pentameroid brachiopods
squamous—scaly, covered with scales
stalk—stem of crinoids
stellate—star-shaped; arranged in star-like manner
stipe—stalk or stem in plants
stock—main stem or trunk
striae—fine radiating surface lines of shells
stylolites—peculiar columnar and striated rock form seen in limestones at the junction of two layers
sub—in composition indicates a low degree: sub-angular—rather angular; sub-carinate—somewhat toothed, etc.

subfusiform—more or less spindle-shaped
subglobose—more or less globose
sublunate—approaching the form of a crescent
suborbicular—nearly circular
subpentahedral—irregularly five-sided
subpyramidal—approximately pyramid-shaped
subquadrangular—between quadrangular and oval
subquadrate—nearly but not quite square
subspheroidal—imperfectly spheroidal
subtruncate—irregularly cut off
subturbinate—approaching top shape
sulcation—a furrow or channel
sulcus—a furrow
superior—higher in position
suture—in cephalopods, the line of junction between shell and septum, seen on breaking away the former; in gastropods, the external line of junction between the several whorls; in trilobites, the dividing line between fixed and free cheks, commonly called *facial suture;* in crinoids, the line of junction between adjacent plates

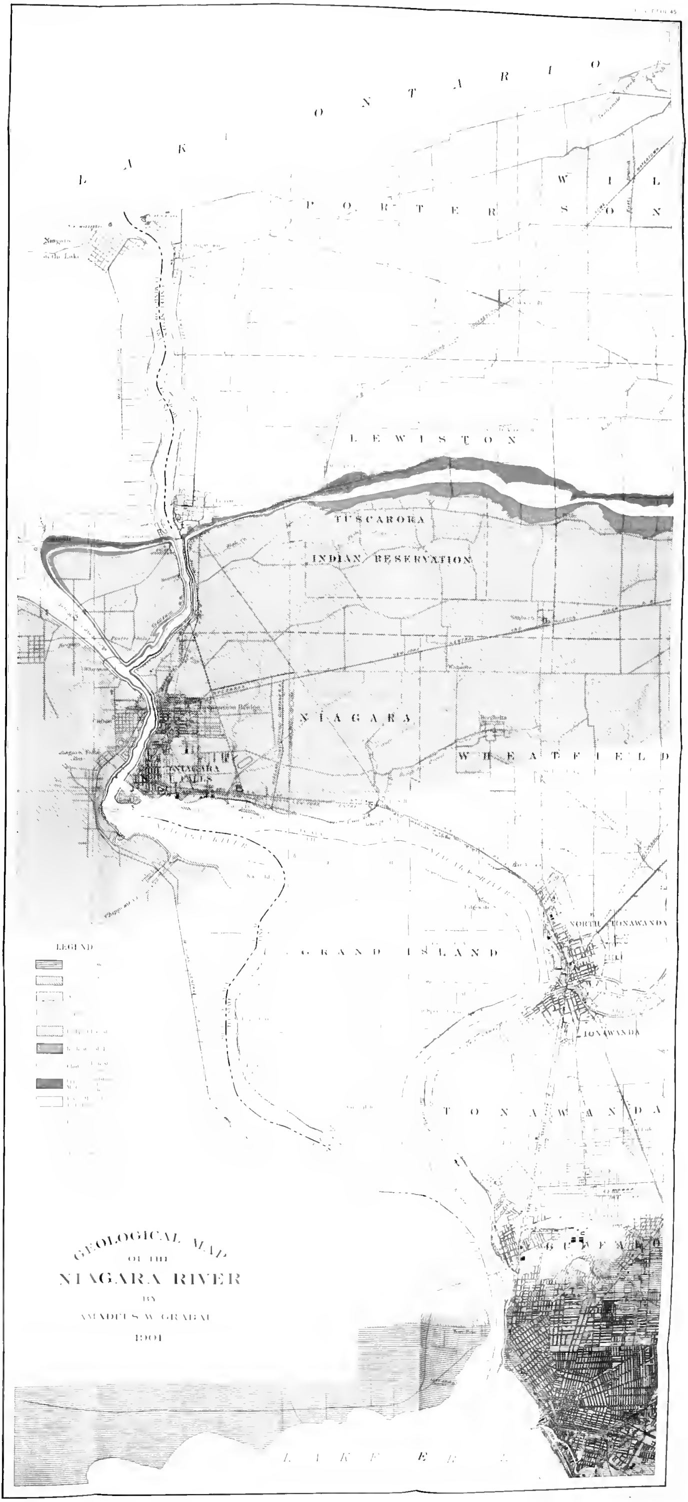
tabulae—transverse, continuous partitions or floors in corals, etc.
tabulate corals—group of corals in which the tabulae cross plates are prominent, while the septa are faintly or not at all developed e. g. Favosites, Aulopora, etc.
talus—the mass of rocky debris which lies at the base of a cliff, having fallen from the face of the cliff above
teeth—articulating projections on the margins of the valves of bivalve shells
tegmen—vault or cover of the calyx in crinoids
terebratuloid—like the recent genus Terebratula
terete—cylindric or slightly tapering terrigenous—derived from the land test-shell
tetracoralla—the old group of rugose corals, built on the plan of four
tetrameral—on the plan of four
theca—the proper wall of the individual corals
thoracic—pertaining to the thorax
thorax—central part of the body of the trilobites
trabeculae—projecting bars
trigonal—three-angled
trihedral—with three equal faces
tripartite—divided into three parts
tripetalous—three leaved or petaled
trochiform—in form like a Trochus or top shell
tubercle—small swollen projection
tuberculiform—in form like a tubercle
tuberculous—having or resembling tubercles
tubicola—an order of marine worms which build calcareous or other tubes
tumid—swollen, inflated
turbinate—top-shaped

umbilicus—external opening of the hollow axis of a loose coiled shell
umbo—area about and including the beak in pelecypods and brachiopods
unconformity—irregularity in the succession of rock beds indicating an intervening period of erosion

valvular—pertaining to a valve
varix—row of spines, a ridge or other mark, denoting the former position of the lip on the shell of a gastropod (plural varices)
vaulted—arched
ventral—pertaining to the lower side, or venter
ventricose—strongly swollen, or bulging
vesicular—bearing vesicles, or hollow cavities
vestibular area—area surrounding the cell apertures of some bryozoa; often depressed
viscera—the internal organs of the body

whorl—single volution of a coiled shell
wing—posterior larger expansion along the hinge-line of a pelecypod

zoarium—aggregates of the polypites of a bryozoan colony
zooecium—the bryozoan cell
zooid—one of the "persons" or individuals of a zoarium


GEOLOGICAL MAP
OF THE
NIAGARA RIVER
BY
AMADEUS W. GRABAU
1901
LEGEND
LAKE ONTARIO
PORTER
WILSON
LEWISTON
TUSCARORA
INDIAN RESERVATION
NIAGARA
NIAGARA FALLS
WHEATFIELD
GRAND ISLAND
NORTH TONAWANDA
TONAWANDA
BUFFALO
LAKE ERIE